DECEMBER • 1946

VOLUME XVIII NUMBER 3

the Petroleum Engineer

...ds for Operating Men

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March 24-27—Western Petroleum Refiners, annual meeting, San Antonio, Texas.

March 24-30—Oil Heat Institute of America, Traymore Hotel, Atlantic City, New Jersey.

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April 7-10—National Association of Corrosion Engineers, annual convention, Palmer House, Chicago.

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COMPACT BENIGN, BUT POTENT

Since its organization more than eleven years ago the Interstate Oil Compact Commission has rendered a valuable service to the oil and gas industry. Acting as an interstate advisory committee, the Compact provides the facilities for the states, by cooperative action, to put into effect the Compact's recommendations in the public interest. In performing this function it has hewed to the line in carrying out the purpose for which it was formed, namely, "to conserve oil and gas by the prevention of physical waste thereof from any cause."

Despite the fact that it has neither the power nor the desire to impose its will on the states, the Compact Commission is perhaps the most potent agency today influencing and fostering sound conservation practices in the production of oil and gas. It provides an open forum whereby all state officials charged with the regulation of oil and gas production can study and discuss the common problem of conservation and attempt to aid in its solution by acknowledging and recommending procedures and practices that will lead to sound conservation and the prevention of physical waste of oil and gas.

Although the Oil Compact Commission's function is limited to the one problem of conserving oil and gas and preventing their avoidable waste within reasonable limitations, a reading of the Compact Commission's proceedings covering the years the Compact has been in force shows that the Commission has greatly broadened the scope of its helpfulness in carrying out this important purpose, with immeasurable benefit to both the oil and gas industry and the general public. What has been accomplished has resulted in an increasing confidence on the part of the oil and gas industry in the soundness of the Compact's provisions and objectives. One thing that has impressed industry is the fact that the Compact Commission has successfully carried on in an atmosphere of mutual trust and helpfulness, and with a minimum of friction, among its member states.

It is now generally recognized and favorably accepted by the industry that the responsibility of producing oil and gas without waste rests upon the individual oil-producing states. The findings and recommendations of the Compact Commission are not enforceable; states may follow them or not, according to whether state officials are convinced they are to the best interest of the state and its citizens. It is this freedom of action on the part of the states, and the lack of enforcement powers on the part of the Compact Commission that, paradoxically, has been an important factor adding to the Compact's prestige and influence.

The Compact Commission is in a position to enlist the cooperation of state officials, including its engineers, economists, and legal talent, and also industry leaders, in making studies and recommendations. It is the work of these standing committees to which can be attributed much of the remarkable progress achieved by the Compact. Included in its present setup are a legal committee, an engineering committee, a regulatory practices committee, a research and coordinating committee, economics advisory committee, public lands committee, and an interstate relations committee. The membership of these committees is selected from the best available legal and engineering talent in the member states.

Reports prepared by the committees represent years of experience in the development and evolution of oil and gas conservation in the various states. The reports are widely distributed and form the background for sound procedure and practice leading to maximum conservation of oil and gas.

Member states in the Compact have increased from six to seventeen. One non oil-producing but prospective oil-producing state, Georgia, has joined the Compact as an associate member. No state has ever withdrawn from the Compact, a tribute to its success and the high regard in which it is held. In addition, no changes have been made in the terms and provisions of the Interstate Oil Compact as originally drafted and agreed upon February 16, 1935, and approved by the 74th Congress on August 27, 1935. The Compact has been extended three times for two-year periods. The last extension was for a four-year period, which expires September 1, 1947.

The efficacy of the Compact in coordinating state conservation efforts has been amply demonstrated. Because of the remarkable results achieved by the Compact, it is expected that the Compact will be made permanent when it comes up in 1947 for consideration by Congress. Regardless of the fact that all producing states are not yet members of the Compact, non-member states have nevertheless given their close cooperation and accepted the findings and recommendations of the Compact, a further indication of its success and the esteem in which it is held by the oil-producing states and by the oil and gas industry. —*K.C.S.*

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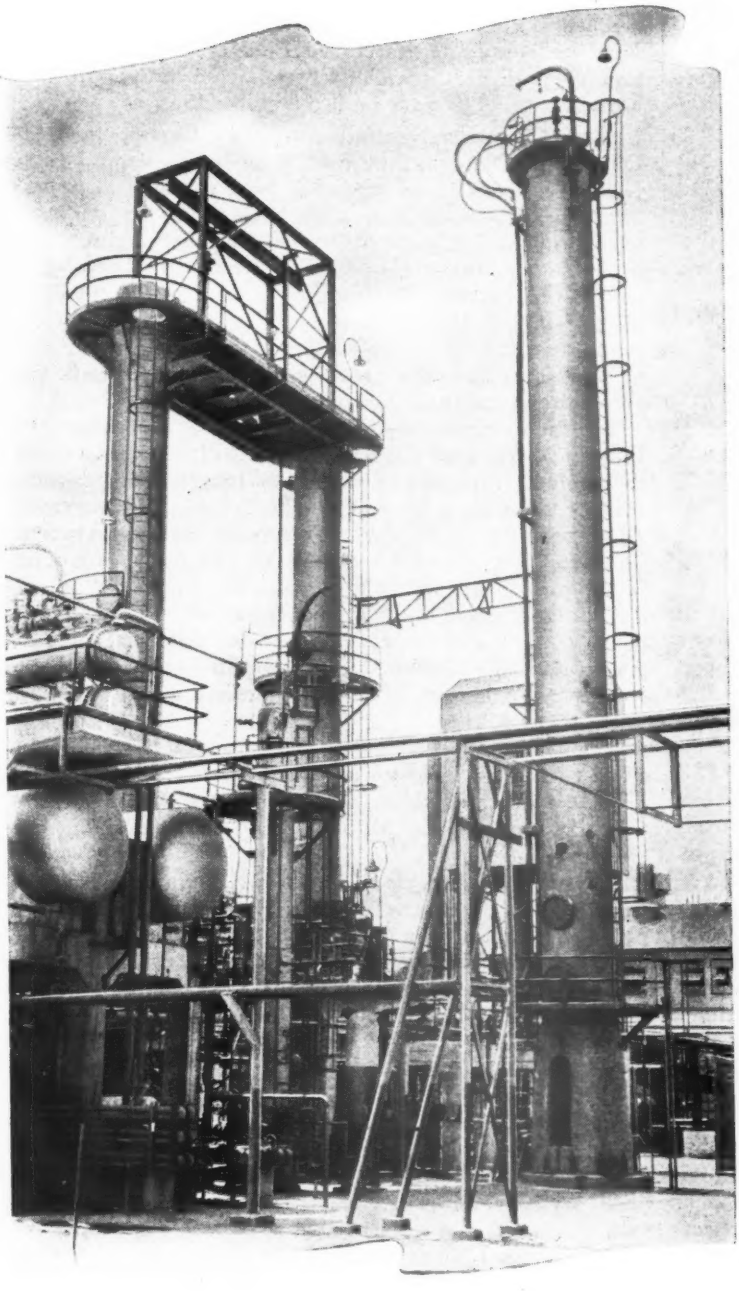

Gasoline production increased by 5 to 6%. Production of 150 to 200 bbls. per day of 82½ octane polymer with a blending value of 100. That's a quick picture of the operation of Frontier Refining Company's new polymerization unit at the Cheyenne Refinery.

But that's only part of the story. This unit was converted from an isomerization unit, operated by the refinery during the war in production of high octane aviation gasoline components. After the war Frontier had to consider how this equipment could be used effectively in producing for a peace time market. An analysis by UOP engineers indicated that this unit could be economically converted into a non-selective catalytic polymerization unit. Most of the existing equipment was utilized and a relatively small investment in new equipment was required. The results speak for themselves.

This is a typical example of the application of UOP research, engineering, processes, and service to a specific refinery problem. A four way technique that is helping refineries all over the world find a profitable solution to the strict demands of their present day operations.

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SCANNING WASHINGTON'S OIL HORIZON

By MILBURN PETTY

WASHINGTON.—The coal strike lasted just long enough for Interior Department to block—temporarily, at least—disposal of the Big Inch pipe lines for oil use.

The issue is now in the lap of Congress, with War Assets Administrator Littlejohn proposing that the government-owned lines be disposed of to the highest cash bidder regardless of use.

But the coal-rail fight against gas use and the petroleum industry's opposition to oil use may result in an impasse such as kept Muscle Shoals unused for years after World War I. It develops now that the rights-of-way through Pennsylvania were contingent on use for "petroleum or its products."

Senator O'Mahoney, Wyoming, is crusading for oil use in the belief that common carrier service would help independent producers and refiners. O'Mahoney has urged this view upon President Truman, personally, and others in topflight administration circles. He can be expected to push this idea when the Big Inch issue comes up in Congress.

Charles H. Smith, New York, president of Big Inch Oil, Inc., the favored bidder—until Littlejohn called all bets off, has announced that he is prepared to pay $100,000,000 all cash for the lines if the government allows him the option of oil or gas use, which might include an oil-gas combination.

This has worried some of the gas bidders who feel that the Federal Power Commission might not be willing to go much above $100,000,000 in setting a rate-making value on the lines for gas transmission. (WAA's appraisal for gas use was $86,-000,000 to which must be added another $40,000,000, more or less, for converting both lines to gas.

The solution may be to use the Big Inch for gas and the Little Big Inch for oil, as proposed in the bid of Trans-Continental Pipe Line Company. It was testified by WAA officials that Trans-Continental had commitments for 186,000 bbl. per day of crude to move through the 20-in. line, should its bid be accepted.

Littlejohn's announcement that he had decided to reject all bids—made on November 19 at opening of Congressman Slaughter's investigation of Big Inch disposal—caught the WAA staff by surprise. They later testified that they had been working on a recommendation that the lines be sold to Big Inch Oil, Inc., for oil use.

In the several weeks preceding Littlejohn's announcement, Interior officials were very active in behalf of using the Big Inch lines for gas.

On October 30, Secretary Krug conferred at Lake Tahoe, Nevada, with Ralph K. Davies, then acting director of Interior Oil and Gas Division. Davies strongly urged that Interior push for gas use of both lines. (Up to that time, Interior had no official policy.)

That same day, Krug telephoned the Interior Department at Washington and gave instructions that Littlejohn be requested to postpone any award on the Big Inches until November 15 because of the threatening coal strike. (The idea was that the lines might be put into gas service immediately as a relief measure, using only natural pressure.) Also, Krug ordered that a survey be made of the possibility of fitting the Big Inch lines into a departmental program for the conservation of flared gas. Littlejohn was contacted and promised that no award would be made until November 15.

A week later, representatives of three Interior units—the Oil and Gas Division, Bureau of Mines and Geological Survey—completed a 15-page report on using the lines to conserve flared gas. It was recommended that some of the gas transported by the Big Inches be used for repressuring eastern oil fields and for storage in depleted gas fields of the Appalachian area. If the operators were required to store 80,000,000 cu. ft. per day, then in 20 years there would be enough gas in storage to supply the North Atlantic seaboard for a whole year in event of another national emergency, allowing the lines to be converted back to oil for military use, the report said.

The following week—that is, the week of November 11—Interior officials used this report as a basis for drafting a letter for President Truman to sign and send back to Krug, directing Interior to make a long-range survey of gas conservation. Along with this, was the draft of another letter for Truman's signature that would have gone to Littlejohn instructing WAA to hold up any award on the Big Inches for 60 days until Interior could study the possibility of using the lines to conserve flared gas. (So far as is known, these letters did not get to the White House before Truman left on his Florida vacation. But he may have been contacted by telephone.)

On November 18, the evening before Littlejohn's bid-rejection announcement, Krug telephoned Littlejohn and asked that WAA hold up the Big Inch award. (Littlejohn's promise expired on November 15 and that day WAA came within a whisker's breadth of deciding in favor of Big Inch Oil, Inc.)

The next morning, Littlejohn took the stand at opening of the Slaughter Committee hearings. He read a statement from pencilled notes announcing that he was rejecting all bids because he thought the government should get within shooting distance of the $113,700,000 appraisal, if the lines went for oil use. Congressional approval would be needed before the lines could be disposed of for gas, he added. So, a new policy report is going up to Congress.

Littlejohn's pipe line negotiators were flabbergasted at this sudden turn of events. They had not known what their chief would say until they heard him testify. Down at WAA headquarters, the real property disposal board (which was to have "final say" according to a previous WAA press release) was still considering the recommendation favoring Big Inch Oil, Inc,. when word came from Capitol Hill of Littlejohn's rejection of all bids.

Two weeks later, on December 5, Littlejohn returned to the stand to insist that the bid-rejection decision "was made by me, personally." He said the decision was reached on November 8 while he was in Kansas City.

After the bids were rejected, Interior moved in and took over from WAA the responsibility for interim use of the lines in gas service, awarding a 120-day lease to Tennessee Gas and Transmission Company just five days before the coal strike ended. Present plans are for continuing the lines in gas service until April 1, operating at partial capacity to supplement gas supplies in the Middle West this winter.

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national petroleum situation

By H. J. STRUTH,* *Petroleum Economist*

EXCESS SUPPLY. Supply exceeded demand in November by 205,000 bbl. daily. On a cumulative basis for the 11 months of this year supply exceeded demand by 201,000 bbl. Crude production in the first 11 months of this year averaged 4,744,000 bbl., natural gasoline and benzol 310,000, and imports averaged 368,000, making a total supply of 5,442,000 bbl. The calculated demand for the 11 months was 5,221,000 bbl.

*Editor, *The Petroleum Data Book.*

STOCK PICTURE DISTURBING. Stocks of all oils between January 1 and November 30 increased 67,271,000 bbl., a daily average of 201,000 bbl. The principal gain was shown in refined products stocks, which increased 175,000 bbl. daily, whereas crude stocks increased 26,000 bbl. daily. The overall stock picture as of December 1 indicates that stocks of all crude and products were about eight per cent above normal working levels.

REFINERY RUNS CUT. Runs to stills in November were reduced 86,000 bbl. daily. For the 11 months of this year runs averaged 4,741,000 bbl. daily, which represented an excess over actual requirements of 41,000 bbl.

CRUDE PRICES. Crude oil prices have advanced this year about 45c per bbl. east of California. The average price for all crudes in the U. S. is $1.64 per bbl., which is about 44 per cent above the 1941 level. This brings the average crude price to within 13 per cent of the 1926 level of $1.88 per bbl.

DRILLING STIMULATED. Wildcat operations in the three months ending November 30 were eight per cent above the same period of last year. Total drilling results this year to date are seven per cent above last year. In view of price advances it was deemed advisable to raise the quota of drilling to approximately 30,000 wells annually. On this basis cumulative drilling results this year are within four per cent of the prewar level.

Comparative Statistics, November, 1946

*All figures are computed on a Bureau of Mines' Basis**

	Nov. 1946(p)	October 1946(p)	Nov. 1945	This year to date	Last year to date	Per cent change
Wells drilling	4,100	4,075	4,155	4,100	4,155	— 1
Total wells drilled	2,517	¶2,493	2,330	26,337	24,689	+ 7
Development wells	2,118	¶2,106	1,969	22,445	20,884	+ 7
Oil	1,242	¶1,246	1,149	13,672	12,671	+ 8
Gas	295	281	264	2,670	2,374	+12
Dry	581	¶579	556	6,103	5,839	+ 5
Per cent dry	27.4	¶27.5	28.2	27.2	27.9	— 0.7
Wildcat wells	399	¶ 387	361	3,892	3,805	+ 2
Oil	41	67	44	553	503	+10
Gas	13	11	10	112	123	— 9
Dry	345	¶309	307	3,227	3,179	+ 2
Per cent dry	86.5	¶79.8	85.0	82.9	83.5	— 0.6
Crude production	143,900	146,650	135,252	1,584,506	1,572,608	+ 1
Daily average	4,797	4,731	4,508	4,744	4,708	
Crude demand‡	144,700	157,550	144,973	1,656,799	1,642,439	+ 1
Daily average	4,823	5,082	4,832	4,960	4,917	
Crude stocks	232,050	225,650	223,526	232,050	223,526	+ 4
Days supply	47	44	46	47	46	
Natural gasoline production	9,470	9,580	9,234	103,572	101,643	+ 2
Daily average	316	309	308	310	304	
Motor fuel production	66,600	68,950	66,873	709,199	733,001	— 3
Daily average	2,220	2,224	2,229	2,123	2,195	
Gasoline yield, per cent	41.9	41.4	42.7	39.6	40.9	— 1.3
Motor fuel demand‡	64,300	67,380	56,554	713,103	730,465	— 2
Daily average	2,143	2,174	1,885	2,135	2,187	
Motor fuel stocks	87,600	85,300	82,416	87,600	82,416	+ 6
Days supply	41	39	44	41	44	
Fuel oil production	55,300	59,230	57,901	657,918	658,931	0
Daily average	1,843	1,911	1,930	1,970	1,973	
Fuel oil demand‡	61,600	54,080	65,018	669,266	717,295	— 7
Daily average	2,053	1,745	2,167	2,004	2,148	
Fuel oil stocks	122,200	¶124,700	85,884	122,200	85,884	+42
Days supply	60	71	40	60	40	
Refinery still Runs	140,700	148,050	138,705	1,583,446	1,577,755	0
Daily average	4,690	4,776	4,624	4,741	4,724	
All refined stocks†	298,800	¶298,900	243,602	298,800	243,602	+23
Days supply	57	61	49	58	49	

Economic Position of U. S. Petroleum Industry

Eleven Months Ending November 30, 1946

	Normal	Actual	Per cent of normal
Drilling*** (wells completed)	¶27,450	26,337	96
Production (daily crude output)	4,726	4,744	100
Refining (daily still runs)	¶ 4,700	4,741	101
Stocks (crude and refined)†	490,025	530,850	108
Price of crude (per bbl.)	$1.88**	$1.64	87

Crude Prices by States for November, 1946

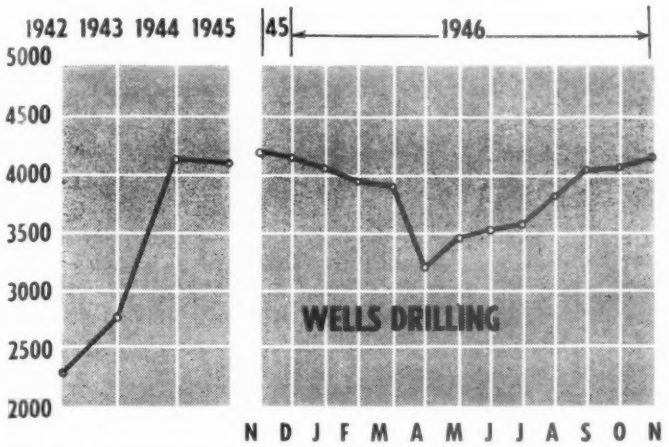
U. S. average	$1.64	Louisiana	$1.67	**Basic crude prices**	
Texas	1.66	Arkansas	1.48	Oklahoma-Kansas (36 gr.)	$1.62
California	1.41	New Mexico	1.45	Texas Gulf Coast (36 gr.)	1.85
Oklahoma	1.68	Mississippi	1.47	East Texas	1.70
Kansas	1.67	Illinois	1.84	West Texas (36 gr.)	1.49
		Other states	2.28	Calif. Signal Hill (26 gr.)	1.46
				Pennsylvania, Bradford	3.10

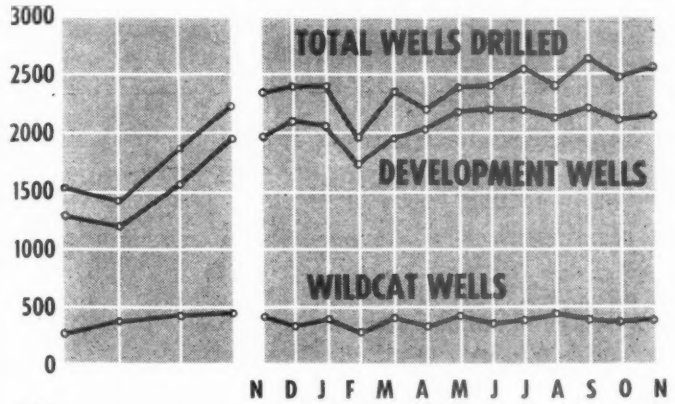
Drilling and Production Statistics by States

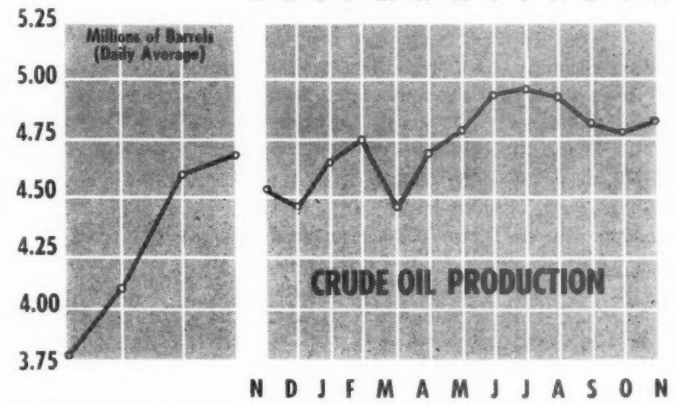
	Nov. 1946(p)	October 1946(p)	Nov. 1945	This year to date	Last year to date	Per cent change
Total wells drilled	2,517	¶2,493	2,330	26,337	24,689	+ 7
Texas	615	624	616	7,190	6,505	+ 9
California	75	84	146	1,378	2,048	—33
Oklahoma	374	326	229	2,751	2,208	+25
Kansas	187	159	167	1,821	1,605	+13
Louisiana	143	140	116	1,278	1,046	+22
Arkansas	17	13	15	162	158	+ 3
New Mexico	31	¶46	26	372	377	— 1
Mississippi	28	24	28	238	341	—30
Illinois	186	228	171	2,156	1,649	+25
Other states	861	¶849	816	8,991	8,752	+ 3
Wildcats drilled	399	¶387	361	3,892	3,805	+ 2
Texas	119	135	146	1,443	1,442	0
California	24	29	16	227	224	+ 1
Oklahoma	84	67	37	505	418	+21
Kansas	45	16	37	284	351	—19
Louisiana	21	20	15	231	157	+47
Arkansas	5	3	4	38	37	+ 3
New Mexico	3	4	3	41	77	—47
Mississippi	8	4	13	68	121	—44
Illinois	45	60	37	470	341	+38
Other states	45	¶49	53	585	637	— 8
Daily crude production	4,797	4,731	4,508	4,744	4,708	+ 1
Texas	2,099	2,049	1,930	2,085	2,083	0
California	865	871	842	862	899	— 4
Oklahoma	358	346	392	368	378	— 3
Kansas	274	279	256	266	265	0
Louisiana	413	406	366	390	357	+ 9
Arkansas	77	77	76	77	79	— 3
New Mexico	103	102	99	101	103	— 2
Mississippi	79	75	51	65	51	+27
Illinois	205	202	209	207	206	0
Other states	324	324	287	323	287	+13

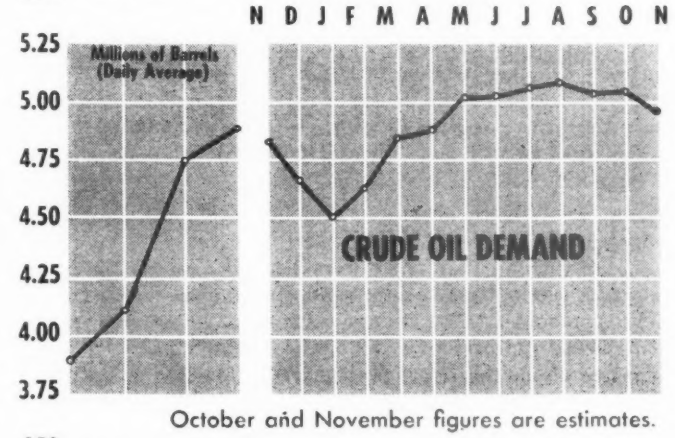
*Unless otherwise stated all figures represent thousands of barrels. ***Does not include input wells. (p) Preliminary
‡Total demand, including exports. ¶Revised. **Price 1926 (Index 100) †Includes natural gasoline stocks.

PRELIMINARY ESTIMATES BASED UPON DATA FURNISHED BY AMERICAN PETROLEUM INSTITUTE, U. S. BUREAU OF MINES, STATE AGENCIES AND OTHER OFFICIAL SOURCES.

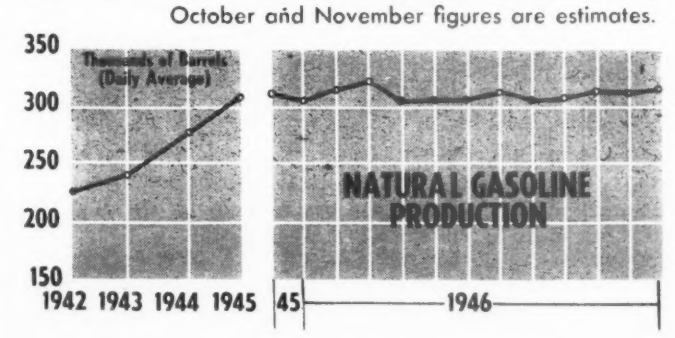


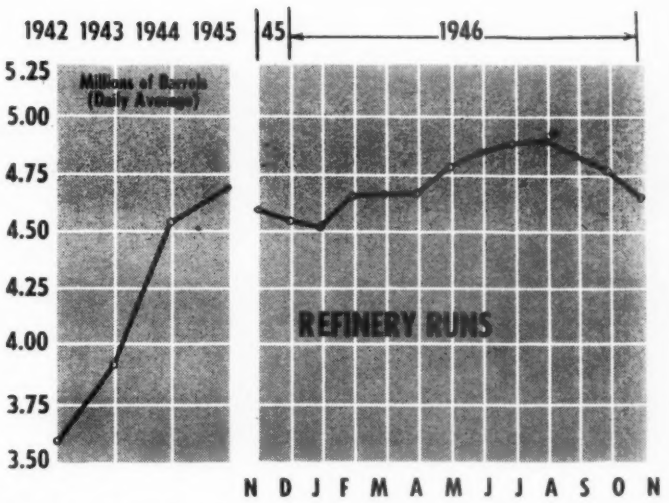


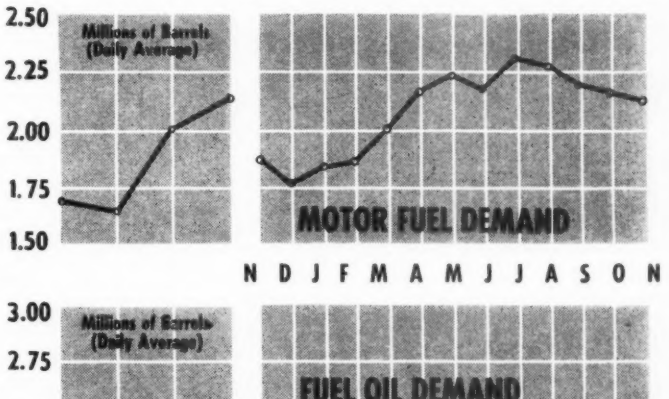


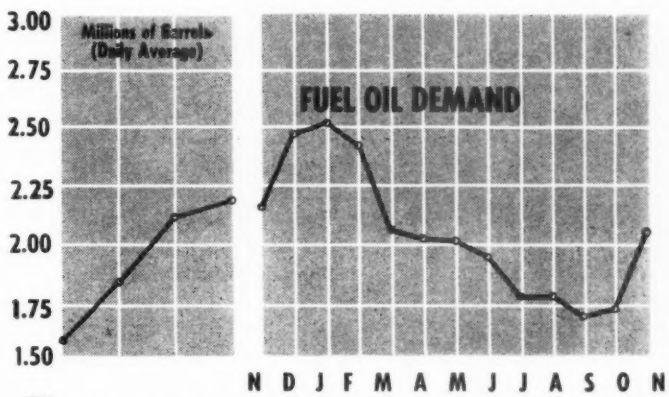


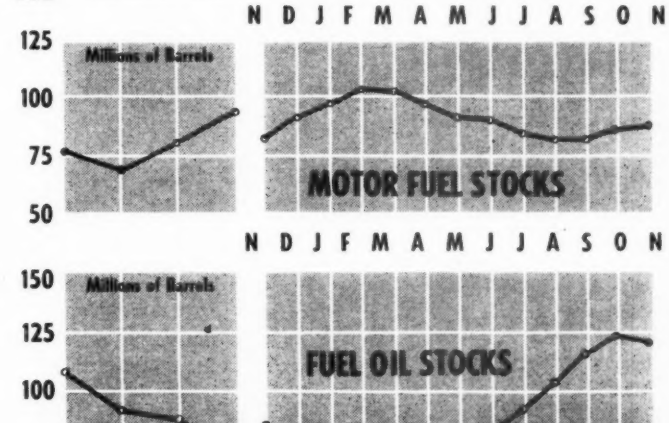
October and November figures are estimates.

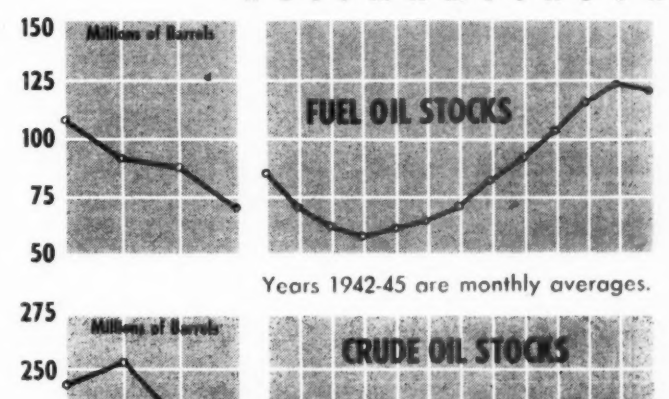




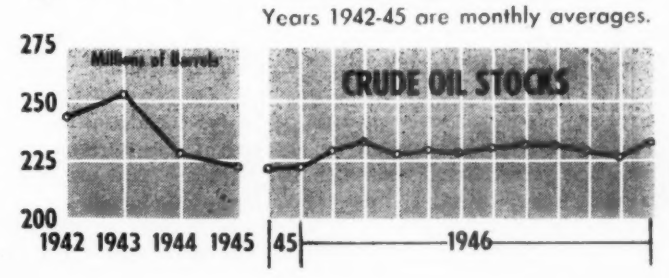




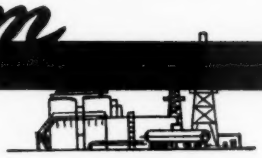




Years 1942-45 are monthly averages.



highlights in oildom



● **BIG INCH FOR GAS TEMPORARILY.** The Department of the Interior early this month entered into a contract with the Tennessee Gas and Transmission Company whereby that company will operate the Big Inch pipe line for the transmission of natural gas for a period of four months. The contract provides that the government will receive a rental of 5 cents per 1000 cu. ft. and the Tennessee company will assume the maintenance contract for which the government is paying $60,000 a month. Before the first gas put into the line had reached its destination, the coal strike had been called off; however, the arrangement continues in effect.

This contract is the result of negotiations conducted by the Department of Interior with four different companies. The three bidders, in addition to the Tennessee Gas and Transmission Company, were Trans-Continental Gas, Inc., Big-Inch Oil, Inc., and Big-Inch Gas, Inc. It is believed that the fact that the Tennessee Gas and Transmission Company was already in operation and had the personnel and equipment available to put the lines into immediate use was what swung the deal in its favor and resulted in the award of this contract. The Tennessee company has announced that it has no interest whatsoever in purchasing the line but is only interested in supplying some of its customers in the industrial area with gas until it can complete a new line now under construction.

It is estimated by company officials that they will be able to transport an average of 100,000,000 cu. ft. of gas a day during the four months' period.

● **CARRIER RULED SUBJECT TO ICC.** The United States Supreme Court recently ruled that the Champlin Refining Company of Enid, Oklahoma, is subject to the authority of the Interstate Commerce Commission, a decision that is of considerable importance to the oil industry. The tribunal split 5 to 4 in its decision.

Champlin owns and operates a 516-mile pipe line from its refinery at Enid to terminals at Hutchinson, Kansas, Superior, Nebraska, and Rock Rapids, Iowa. It is used to transport refined oil products owned by Champlin.

The company contested an ICC order requiring it to file information for use in valuation of the pipe-line properties. The firm maintained that it did not transport oil products within the meaning of the act.

A special three-judge federal court in the western Oklahoma district decided the company was a common carrier within the meaning of the Interstate Commerce Act. The company contended the decision applying the definition to every interstate oil pipe line, regardless of the purpose for which it is used, and that the district court had erred in holding it was engaged in transportation in commerce within the meaning of the Interstate Commerce Act.

The Supreme Court's decision said the ICC act provides that the definition "common carrier" includes all pipe-line companies.

"The power of Congress to regulate interstate commerce," it said, "is not dependent on the technical common carrier status but is quite as extensive as over a private carrier."

The Supreme Court recognized that the company has never been asked to carry the products of another over its pipe line; however, the court continued, the ICC has yet made no order that changes the company's obligations to any other company or person. If it does, the high court said, it will be timely to consider concrete requirements and their specific effects on the appellant, the Champlin company.

The dissenting justices took the position that the company was not a common carrier within the meaning of the act. They took the view that when a company is simply drawing oil from its own wells across a state line to its own refinery for its own use, and no more, it is not interstate transportation within the meaning of the Interstate Commerce Act.

● **IRANIAN CONCESSIONS.** The Iranian Government has decided to grant oil concessions to American companies in southern and southeastern Iran, according to the newspaper *Rahbar,* Tehran. The report was attributed to informed circles attached to the government.

● **EXPLORATION PROGRAM FOR SPAIN.** Equipped with American drilling machinery, a new oil exploration program is scheduled to get underway soon in Spain, now completely dependent upon imports for all classes of motor fuels and petroleum products.

An American-made rig has reached Spain, and it is expected the first test hole will be drilled around Lerida, about 75 miles west of Barcelona, Spain's industrial metropolis on the Mediterranean. Plans call for test wells around 5500 ft., almost twice the depth of previous wildcats in the country.

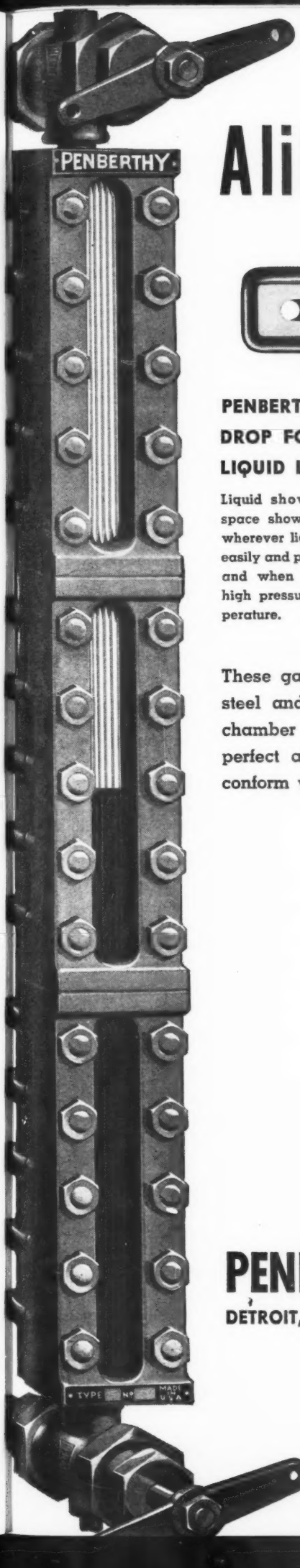
Other test locations include Burgos, Generalissimo Franco's civil wartime headquarters, and Malaga, the "Miami" of Spain on the southern Mediterranean coast. Significant seepages reportedly have been found around Malaga.

The new hunt for oil will be made by the Compania Espanola de Petroleos Scientificas Investigacioes, SA, which is known as Cepsisa.

● **RADAR IN RIVER TRANSPORTATION.** That the use of radar will make an important advancement in the efficiency of river transportation is the belief of Paul G. Blazer, chairman of the board of the Ashland Oil and Refining Company, as a result of the successful completion of an experimental trip made by his company's diesel-powered towboat Tri-State.

Capt. Kent Booth, master of the Tri-State, said the radar equipment on his boat showed clearly the shore line of the river, approaching craft that were beyond view of the eye, boats tied to the bank, bridges and power lines crossing the river, approaching craft that were beyond view of the eye, radar showed approach of other towboats obscured from view around bends in the river, he said. A normal radius of two miles was used, but when the scope was increased to 30 miles, the movement of storm fronts was shown.

● **TEXAS TO OFFER LEASES 27 MILES INTO GULF.** The Texas School Land Board expects to sell oil and gas leases for 27 miles into the Gulf of Mexico next year, Bascom Giles, land commissioner, reports. Twelve thousand acres of tidewater have been leased by this board so far, all close to shore. One hundred sixty-four oil and gas wells have been discovered, Giles said. Extending leases 27 miles will make available 7,000,000 acres, he said. A well is being drilled 25 miles off Louisiana's coast, and several inquiries have come concerning distant offshore leasing in Texas, Giles said.



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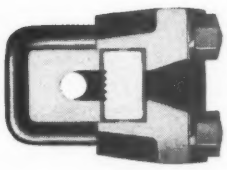

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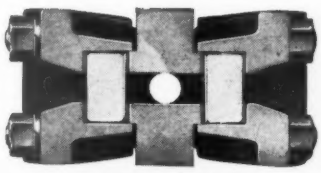

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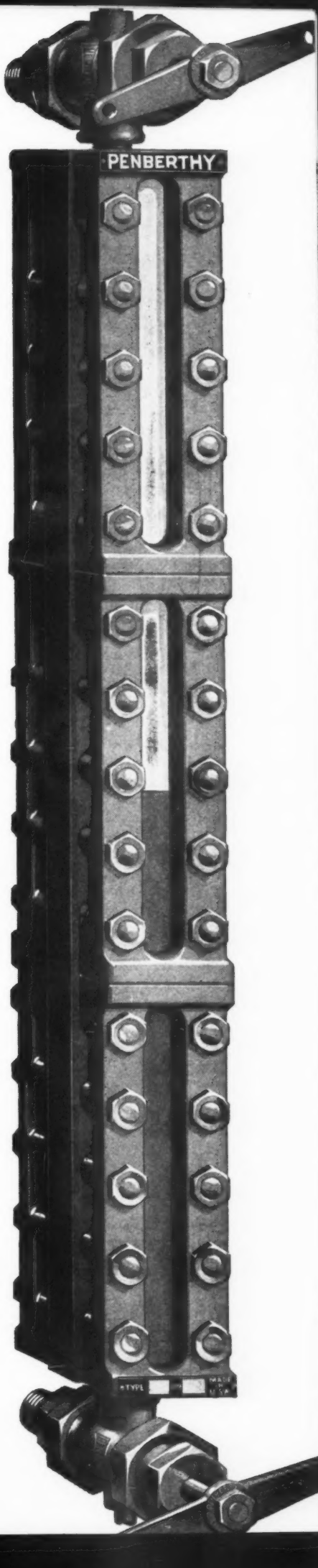

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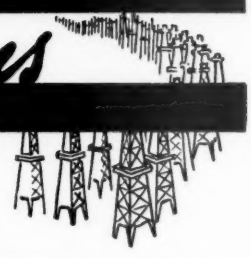
PENBERTHY PRODUCTS

current oil field operations



● **CALIFORNIA.** With O. M. Evans, vice president of field operations for Pacific Western Oil Corporation personally directing the project, a Loffland Brothers drilling crew, led by tool-pusher Cotton Holder, nursing it as a mother nurses a baby; and Doug Marcell and Warren Craddock shouldering the petroleum engineering burden alternately, Pacific Western's deep well, National Royalties No. 1, some nine miles east of the northern end of the Lost Hills field in the San Joaquin Valley, has already broken at least five world's records.

The well already has beaten the former record-holding Phillips Petroleum Company's well in Brazos County, Texas, and stands bottomed at 16,670 ft.

Besides being the deepest oil well in the world, Pacific Western's Lost Hills wildcat boasts the largest diameter hole ever drilled to such depths. At bottom the hole is 8⅜ in. The well has 13⅜-in. surface pipe cemented at 1488 ft., and a string of 9⅝-in. to 9434 ft. Another world's record is to be found in the combination string, which is made up as follows:

4½-in.—18.1 lb./ft.	6347 ft.
3½ in.—15.5 lb./ft.	10,103 ft.
Drill collars	205 ft.
Kelly	13 ft.
Total	16,668 ft.

This means an approximate total weight for the combination string of 270,000 lb.

The well was cored from 16,538 ft. to 16,544 ft., the lowest depth at which an oil well was ever cored.

The present depth of 16,670 ft. was reached in an overall elapsed time of 216 days, which constitutes another record.

● **COLORADO.** Promise of a new oil field in northwestern Colorado is indicated with the completion by Continental Oil Company of a wildcat in Moffat County, Margaret Smith No. 1, 28 miles northeast of Rangely field. The well swabbed 200 bbl. of 30 gravity oil on a 24-hr. test, according to W. C. MacMillan, Continental vice president in charge of production. Production is in the Weber sand at 6097-6126 ft., the same zone from which oil is produced in Rangely.

● **LOUISIANA.** Macmillan Petroleum Corporation and C. H. Murphy, Jr., have completed an exceptionally high gravity oil well in the Cotton Valley area of Webster Parish believed to open a new field of importance. The crude tests 51.8 gravity. The owners estimate potential production of the well at 1200 bbl. daily. Production is from 5722-28 ft.

● **NEW MEXICO.** Sun Oil Company No. 1-B McKinley, 20-18s-38e, is a prospective lower Permian discovery in Lea County between Hobbs and Livington. Total depth is 7656 ft.

● **WYOMING.** Continental Oil Company has discovered a new oil producing zone in Wyoming's Circle Ridge field. Shoshone No. 4, on the Shoshone Indian reservation, 50 miles northwest of Riverton, tested approximately 200 bbl. a day at 1600-65 ft., in the Madison lime. Other production in this immediate area is from the Embar-Tensleep zone, varying in depth from 275 to 800 ft.

● **MICHIGAN.** Carter Oil Company has opened a Traverse lime pool in Oceana county, 18 miles north of the Muskegon pool, with No. 1 Miller, 1-13n-18w. It made a flow of oil over the top of the derrick from the Traverse lime at a total depth of only 1629 ft.

● **TEXAS.** A new Ellenburger, lower Ordovician, oil pool for Stephens County, has been completed as the L. C. Harrison No. 1 Compton, 5 miles southeast of Ibex. The discovery was completed to flow 192 bbl. of 45 gravity oil in 4 hours with pay from 4260-80 ft.

Eason Oil Company's new discovery in Montague County, No. 1 Temple Yarbrough, F. J. Fellows survey, was deepened from 4104 ft., where it first tested for a producer, to 4122 ft. An unreported amount of oil was tanked.

Floyd L. Karsten No. 1 Reitz, E. T. survey No. 50, indicated a new Wharton County pool 5 miles southwest of El Campo. It cored saturated sand around 6800 ft.

New Bend Conglomerate oil production for Clay County has been opened by Jack Grace of Wichita Falls, with No. 1-C Edwards, 7 miles southeast of Henrietta. The producer was completed to flow at an estimated rate of 50 bbl. of better than 40 gravity oil an hour from 6070-86 ft.

A new Permian discovery is the Fred Turner No. 1 Fisher-Shell, 16-A36-PSL, which was completed on pump from 4456 ft. in the San Andres. It is rated at 250 bbl. a day.

Southwest of Flynn, Leon County, the J. B. Daniel No. 1 Cox, Scritchfield survey, is a definite Woodbine producer from 7036-428 ft. Early output was 6 to 9 bbl. an hour.

Union of California has an indicated discovery in Andrews County in its No. 1-F Means, 1-A46-PSL, three miles southwest of the Means pool. Shot with 180 qt. from 4615-90 ft., the well flowed oil with no water with no gauge taken.

Prospects of a new field is indicated by Sun Oil Company No. 1 Jameson, Coke County, which recovered 500 ft. of 44 gravity and gas estimated at 2,000,000 ft. daily on a 45-min. drillstem test from 6206-30 ft. in the Pennsylvanian.

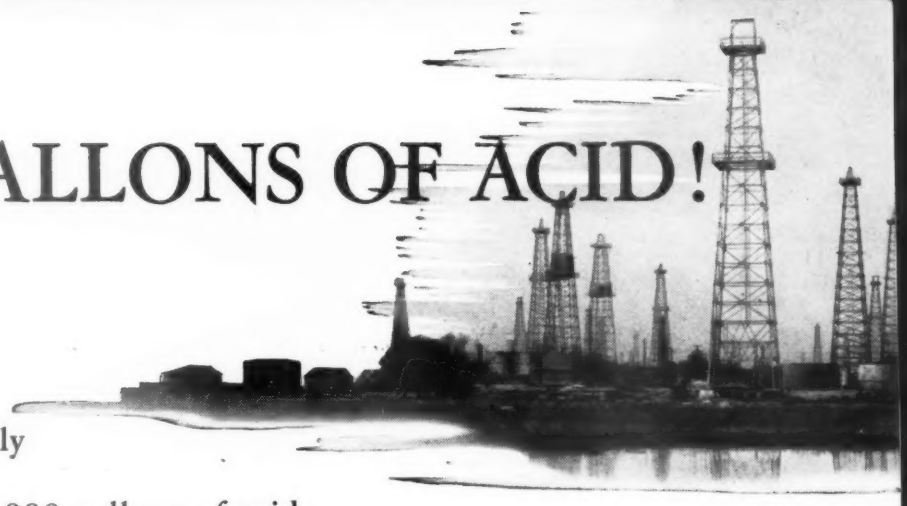
National Associated Oil Company and The Texas Company No. 1 Crouch, 24-16 H&TC survey, Palo Pinto lime discovery in west central Wilbarger two miles north of Tolbert, has been completed to flow 174 bbl. of oil in 24 hr. Production is from 5015-40 ft. and 5068-81 ft.

● **VENEZUELA.** Discovery of a new oil field in Venezuela was announced by Pantepec Oil Company of Venezuela. Well No. 1 on the Pelayo concession in Venezuela, jointly owned by Pantepec and The Atlantic Refining Company, began flowing from 7473 and 7488 ft. A 7-hr. test showed production of 425 bbl. of 30.5 deg. gravity oil daily.

Phillips Venezuelan Oil Company, a wholly-owned subsidiary, has completed three oil wells capable of flowing from 250 to 400 bbl. per day on small size chokes. Drilling operations are now in progress on seven additional wells, two of which are coring the pay zone preparatory to completing. All company wells drilled in Venezuela, including the initial exploratory well, have been producers.

● **HUNGARY.** The Hungarian government has announced that an oil exploration party discovered the presence of oil in the Danube-Tiza basin about 70 miles southeast of Budapest. Informed sources say this area does not come within holdings of Soviet Hungarian Oil Company formed some months ago.

145,000,000 GALLONS OF ACID!



Treating records show that Dowell engineers have successfully handled more than 145,000,000 gallons of acid.

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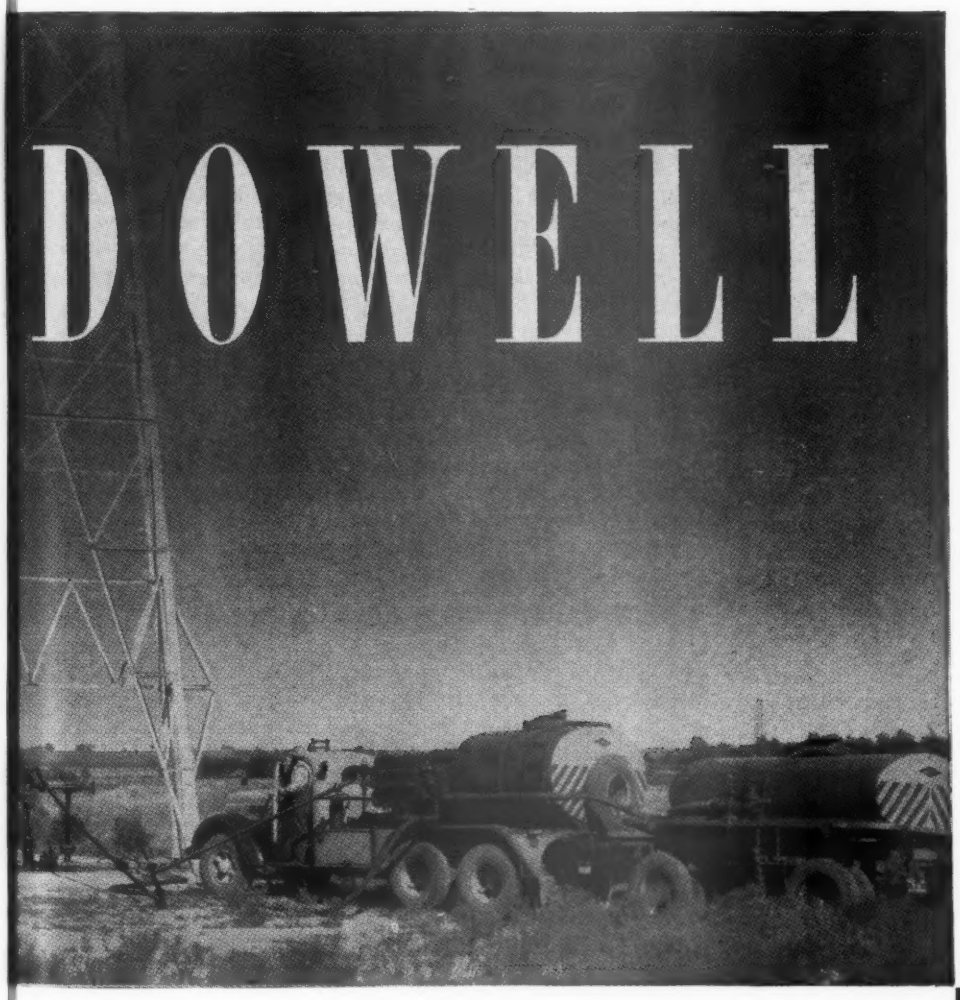

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Dowell's complete acidizing service includes field equipment engineered for oil and gas well service, adequate supplies of correct chemicals and conveniently located treating stations. This service is backed by the extensive research facilities of its parent organization, The Dow Chemical Company.

And, *most important*, Dowell acidizing service makes available to you the accumulated experience of competent engineers who know their business—and can adapt the most modern developments and techniques to solving *your* problems.

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Well completed in the Arbuckle formation. Acidized in 2 stages of 750 gallons and 1250 gallons. Production before acidizing—24 barrels of oil (no water) per day. After first stage—120 barrels oil and no water per day. After second stage—288 barrels oil and no water per day.

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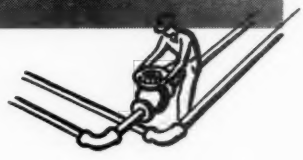


● **HUGE PROGRAM OUTLINED.** The Tennessee Gas and Transmission Company, Houston, Texas, has applied to FPC to construct natural gas pipe line facilities to increase its delivery capacity by 219,000,000 cu. ft. a day, bringing total delivery capacity to 600,000,000 cu. ft. daily. The company estimated the construction costs at $59,545,000.

New facilities proposed include a 6000-hp. compressor station to be located in Nueces County, Texas, the addition of 81,600-hp. compressor units to existing compressor stations, construction of about 648 miles of 26-in., 68½ miles of 24-in. and 82 miles of 20-in. main line loop along the company's 24-in. main transmission line, and various lateral gas gathering lines to connect to its system the additional required supplies of natural gas.

Tennessee Gas and Transmission supplies natural gas to United Fuel Gas Company, Hope Natural Gas Company, Kentucky Natural Gas Corporation, Louisville Gas and Electric Company, Taylor-Green Gas Company and Tennessee Natural Gas Lines, Inc., for resale for ultimate public consumption in Tennessee, Kentucky, West Virginia, Ohio, Pennsylvania and New York.

● **WEST VIRGINIA EXPANSION.** The Hope Natural Gas Company, Clarksburg, West Virginia, has applied to the Federal Power Commission for permission to construct additional natural gas transmission system facilities in West Virginia during 1947 and 1948. The new facilities would enable the company to receive larger quantities of gas to be supplied by Tennessee Gas and Transmission Company. Under a proposed supplement to the agreement between the companies, Tennessee is obligated to deliver, beginning January 1948, up to 165,000,000 cu. ft. of gas a day to Hope and a maximum of 200,000,000 cu. ft. per day during 1949. The present deliveries total a maximum of 115,000,000 cu. ft. a day. Hope estimated cost of new facilities at $4,700,000.

● **MICHIGAN LINE APPROVED.** The FPC authorized a new $84,000,000 natural gas pipe line between Texas and Michigan and Wisconsin.

The decision enables the Michigan-Wisconsin Pipe Line company to build 1076 miles of line with 892 miles of branch line from the Hugoton gas field in Texas.

The new line would take natural gas to Wisconsin consumers for the first time, serving Milwaukee, Madison, Oshkosh and Janesville; it also will increase the amount of gas available to industries in Detroit, Michigan.

The commission also authorized Panhandle Eastern Pipe Line company to construct $23,644,000 of additional facilities to its Texas-Michigan natural gas pipe line system.

● **PIPE LINE DIRECTORY.** A 1947 directory listing companies, executives and operating personnel of the pipeline industry in the United States and Canada is now available for distribution by the Midwest Oil Register, Tulsa, Oklahoma, it was announced by C. L. Cooper, publisher. The pocket-size publication lists over 3,500 individuals together with titles and mailing addresses. It gives the miles of pipe line by sizes for crude, products and natural gas and the number and location of pumping stations.

● **AUGMENT SYSTEM.** Sunray Oil Corporation will construct 83 miles of 8-in. pipe line from its Allen, Oklahoma, refinery to Drumright, as soon as equipment can be obtained. Cost will be approximately $1,000,000.

At Drumright the line will form a connection with the Great Lakes Pipe Line Company's system, facilitating deliveries of Sunray's products to northern and northeastern sections of the country. Sunray will construct a pumping station at Allen, capable of handling a pipe line throughput of about 20,000 bbl. of gasoline a day. The Sunray line will also receive gasolines produced at the Wilcox Oil and Gas Company's Bristow refinery, for delivery into the Great Lakes company's system. Wilcox will have half ownership of that portion of the line between Bristow and Drumright, a distance of about 16 miles.

● **PROPOSE 836-MILE LINE.** Mid-Continent Gas Transmission Company was before the FPC in Kansas City this month presenting its case for permission to build a pipe line from Liberal, Kansas, to St. Paul, Minnesota. Maximum demand for the proposed 836-mile line was estimated at 326,690,000 cu. ft. of gas the first year of operation, rising to 464,690,000 cu. ft. in the fifth year.

The hearing is closely attended by attorneys for Cities Service Gas Company, which has applied for permission to construct a line from Hugoton, Kansas, to Kansas City, and the Northern Natural Gas Company, which wants authority to extend its line into Iowa and Minnesota.

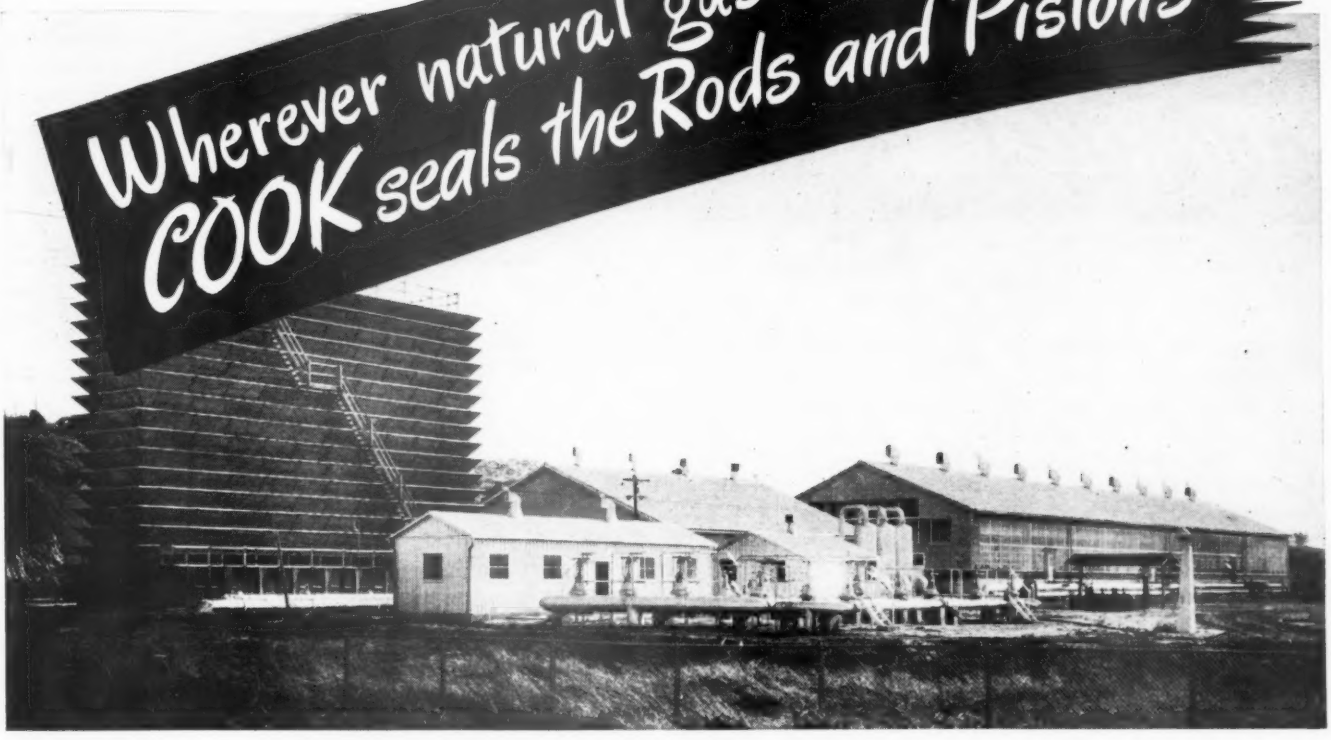
● **OHIO PROJECT.** The Ohio Fuel Gas Company, Columbus, Ohio, plans to construct facilities enlarging its transmission system to receive additional natural gas deliveries from the United Fuel Gas Company, and to store gas received from Panhandle Eastern Pipe Line Company for delivery in peak periods. Costs were estimated by the company at $3,370,100, with some savings from salvage. Construction will be completed during 1947.

Facilities authorized include an underground natural gas storage project in Lorain and Medina counties, Ohio, to be known as the Wellington storage project, construction of a 200-hp. compressor station in Lorain county, a 2400-hp. compressor station in Lawrence county and about 88 miles of 16-in. gas transmission lines in Lorain, Fairfield, Licking, and Knox counties. The Wellington project will consist of three pools covering about 5,225 acres.

● **N. Y. EXPANSION PLANNED.** The New York State Natural Gas Corporation, New York City, has applied to FPC for permission to construct during 1947 and 1948 facilities to increase the capacity of its transmission and storage system to meet anticipated gas requirements of 15 present and potential customer companies in Pennsylvania and New York. Costs were estimated at $5,250,000, to be financed by sale of securities.

The company proposed addition to its system during 1947 of about 70 miles of 12¾-in. and 50 miles of 14-in. line loop and about 14½ miles of 16-in. transmission pipe line in Pennsylvania to accommodate a total of 90,000,000 cu. ft., of gas to be received daily from Hope Natural Gas Company in accordance with a recent amendment to the contract between the companies. In addition, New York State Natural would add three 300-hp. compressors to the Boom compressor station so that it would be able to store and withdraw larger quantities of gas in the Boom Storage pool. The facilities planned for construction in 1948 include 21 miles of 12¾-in. and 10 miles of 14-in. loop line to be used to receive 100,000,000 cu. ft. of gas daily from Hope Natural Gas Company.

Wherever natural gas is compressed COOK seals the Rods and Pistons



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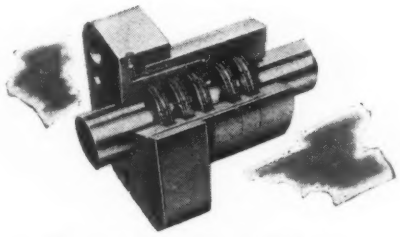

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refining and natural gasoline activities

● **NEW OIL PRODUCTS.** The number of new, everyday materials that can be and are being made from petroleum and natural gas "staggers the imagination," Robert P. Russell, president of Standard Oil Development Company, declared at the annual meeting of the Southern Research Institute. The head of the central research organization of Standard Oil Co. (N.J.) listed among the new products resulting from research and development in the petroleum industry: Synthetic soaps of superior quality; a type of resin that can be made into thin sheets and wrapped around perishable food products, keeping them fresh during weeks of storage; cheaper but highly effective fungicides and insecticides, a synthetic gasoline from natural gas that already appears to be competitive with gasoline from oil.

Russell also reported work on improved anti-knock gasolines that will give about 50 per cent more mileage and reduce motor fuel costs. The new gasolines, he noted, can be made to operate in cars of the future that have engines of a higher compression ratio than are presently used. He quoted automotive authorities as saying these cars of tomorrow with high compression engines can be built at the cost of present day cars.

● **LEASES U. S. PLANT.** Paul G. Blazer, chairman of the board of Ashland Oil and Refining Company, announced that the company arranged with the War Assets Administration to lease the $16,000,000 government-owned and Ashland-operated refinery at Leach, Kentucky, to process high octane gasoline for automobile use. An improvement program costing more than $1,000,000 is under way.

● **GLYCERIN PLANT TO BE BUILT.** Shell Chemical Corporation has announced a $7,000,000 plant for commercial production of synthetic glycerin to be built in Houston, Texas.

Jan Oostermeyer, president, said the plant will be completed early in 1948 and will utilize a process developed in the laboratories of Shell Development Company at Emeryville, California, to convert propylene, chlorine and caustic soda into glycerin.

In addition to explosives, glycerin is used for surface coatings for automobiles and refrigerators, in cellophane, films and toilet articles.

● **NEW MEXICAN UNIT IN PRODUCTION.** Atzcapotzalco, a new refinery situated just outside Mexico City, is now in full operation. Gasolines being processed are 82-octane and 72-octane, which is higher in octane content than any gasoline previously processed in Mexico.

A sum of $8,000,000 is said to have been spent at crude oil sources in order that the supply may be ample for the new refinery, as well as for the old plants. Another $2,000,000 was expanded to facilitate transportation, reports stated.

● **RUSSIA REPORTS NEW PROCESS.** The Soviet petroleum industry, in cooperation with research institutions, has developed a new domestic catalytic cracking process to obtain high octane gasoline, according to a Soviet press report carried by Foreign Commerce Weekly. The tests are being made at a pilot plant in the city of Grozny, it is said.

High octane gasoline was produced from naphthyl and paraffin in the experimental distillations. The report states that the results of these experiments will serve as a basis for a more widespread use of the catalytic cracking process in the distillation of petroleum.

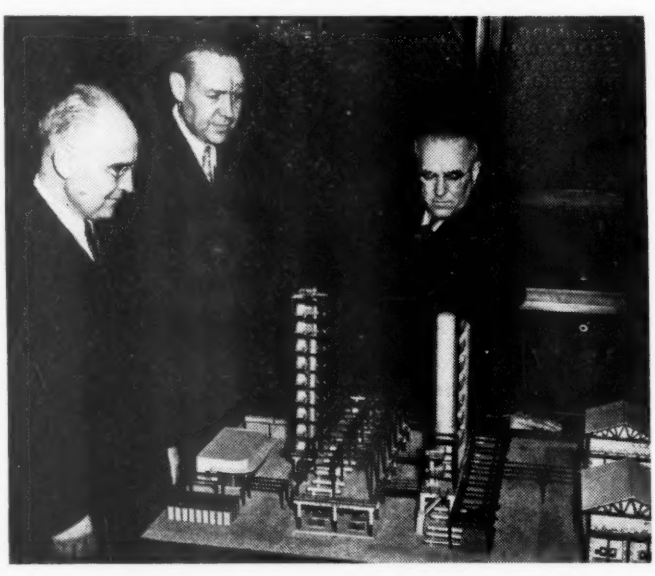
● **ENGLISH UNIT TO EXPAND.** A £10,000,000 expansion program for the Fawley refinery, near Southampton, has been submitted to the British government for its approval. Owned by Agwi Petroleum Corporation, a subsidiary of Anglo-American Oil Company, the plant is one of the largest in England with an input capacity of 600,000 tons a year. With the expansion completed this is expected to be increased to 3,000,000 tons per year.

● **SHELL BEGINS NEW UNIT.** The Shell Oil Company, Inc., will begin construction immediately on a multi-million dollar lubricating oil manufacturing plant adjacent to the company's present refinery on the ship channel, P. E. Foster, manager of the refinery, said.

The plant will cover 75 acres of land in the 650-acre tract purchased last year to provide for Shell's post-war expansion program. The new lube plant will be in addition to the extensive construction project recently completed at the refinery, which includes a 22,000-bbl. per day catalytic cracking unit, gas recovery and treating equipment. According to Foster, the new lubricating oil facilities will consist of five separate plants of the latest design, embodying improvements developed to meet war-time needs or resulting form war-time research. Included in the installation will be plants for vacuum distillation, de-asphalting, solvent extraction, de-waxing, and chemical treating. The new refinery units, when finished, will be able to completely process high, medium, and low viscosity indexed lubricating oils from Southwest crudes.

Foster said that contracts for construction had been awarded to the Lummus and the M. W. Kellogg companies.

P. E. Foster (right), manager of Shell's Houston refinery; O. M. Morfit (left), M. W. Kellogg Company; and W. W. Kraft (center), Lummus Company, examine a model of a vacuum distillation unit similar to one that will be installed in the large lubricating oil manufacturing plant now under construction in Houston for the Shell Oil Company, Inc.



THE Petroleum Engineer

DECEMBER, 1946

Knock-free power

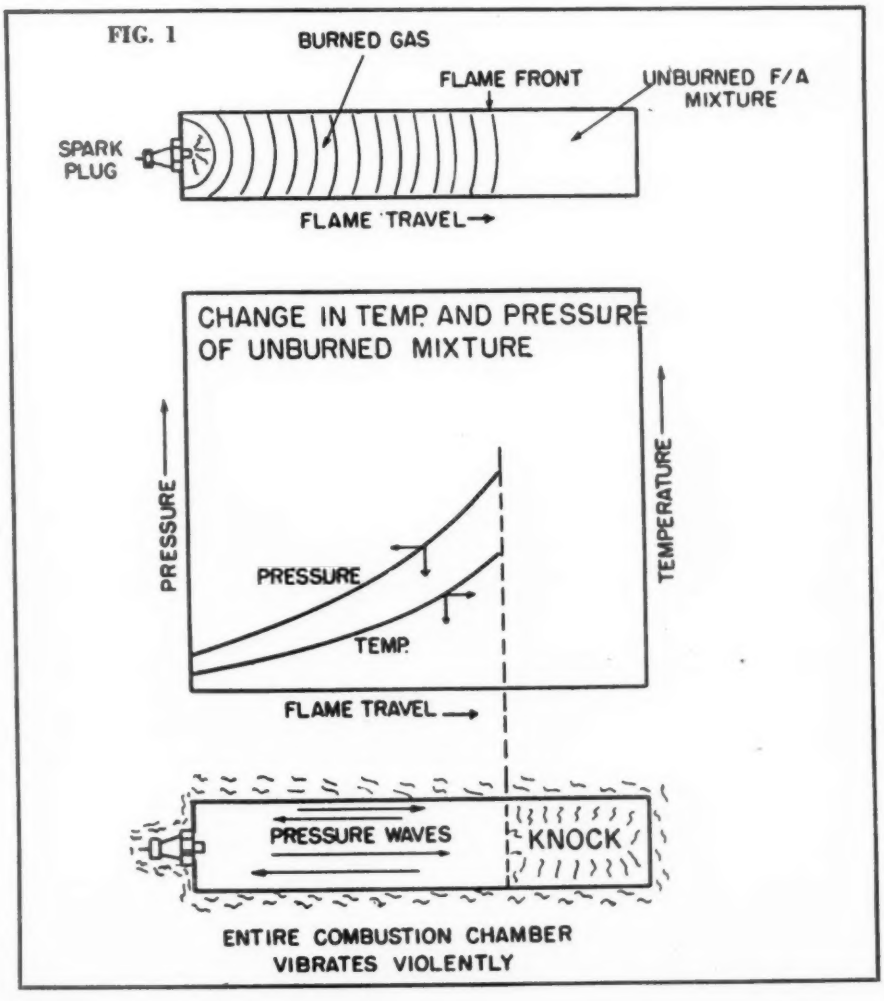
By PETER J. GAYLOR

EXCLUSIVE

According to our present knowledge, knock is caused by the spontaneous ignition or disintegration of the unburned portion of the charge. If the fuel is ignited in the cylinder, and it burns slowly enough so that the energy build-up in the unburned portion is not fast enough to cause spontaneous ignition, a smooth combustion will take place. On the other hand, if the rate of burning is too fast, or the spontaneous ignition temperature (S.I.T.) of the charge is very low, the combustion will proceed across the cylinder until the energy build-up in the unburned portion reaches the critical conditions for its spontaneous ignition, whereupon a simultaneous explosive combustion of that portion occurs, resulting in a detonation wave commonly known as knock. This is illustrated[1] in the lower part of Fig. 1.

In the case of diesel engines, no spark is employed and the combustion proceeds almost entirely through the means of spontaneous ignition, so that it can be expected that spontaneous ignition data obtained under engine conditions should correlate somewhat better with knocking data, and such has been found to be the case in some Russian[2] work, as shown in Fig. 2. In those experiments, engine conditions were estimated to be 580°C. and 215 atm., and the time lag before ignition in a bomb under those conditions was

FIG. 1



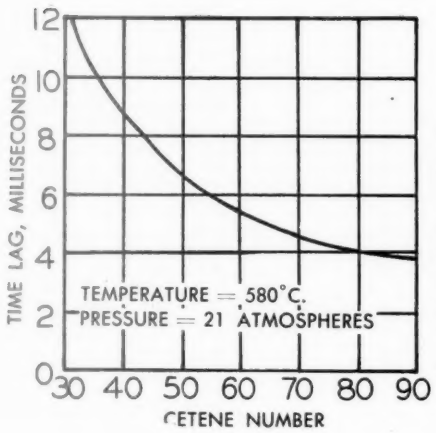


FIG. 2

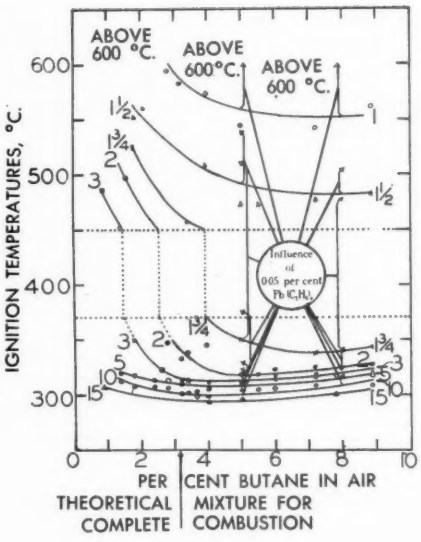


FIG. 3

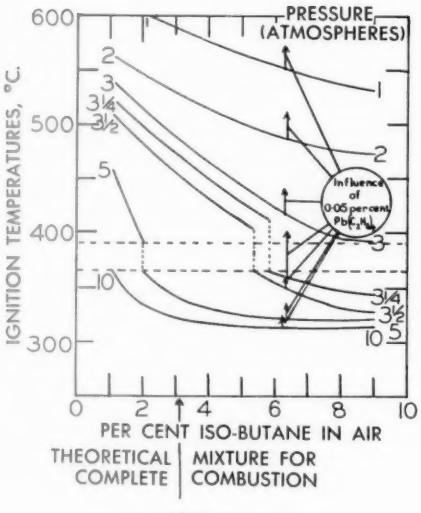


FIG. 4

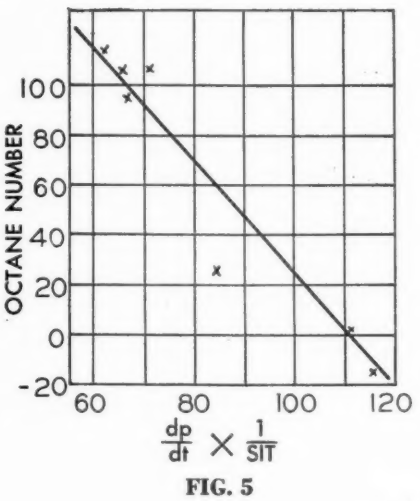


FIG. 5

TABLE 1

Static spark ignition bomb data.

(100°C., 95 lb. per sq. in., initial conditions)
(Brit. Aeron. Res. Comm. data)

F/A	$a°$	t_1	t_2 (sec.)	t_1+t_2	P (max.), (lb. per sq. in. abs)	Max. $\frac{dp}{dt_2}$	Noise
			n-Hexane				
0.059	33	0.043	0.042	0.085	671	16,000	Slight squeak
0.068	43	0.031	0.040	0.071	719	17,900	Just heard
0.076	58	0.027	0.036	0.063	720 (d)	20,000	Fairly loud squeak
0.093	78	(0.038)	....	....	(d)	....	Loud high short squeak
			Benzene				
0.060	28	0.053	0.040	0.093	629	15,700	Not heard
0.068	43	0.035	0.036	0.071	682	18,900	Not heard
0.076	51	0.027	0.030	0.057	720	24,000	Slight dull squeak
0.083	55	0.023	0.030	0.053	744	24,800	Slight squeak
0.094	63	(0.026)	(0.022)	(0.048)	741 (d)	33,600	Moderate squeak
0.109	76	....	....	....	(d)	....	High metallic knock
			Gasoline (Shell avia. spirit, 1920, sp. gr. 0.727)				
0.052	31	0.096	0.074	0.160	592	8,000	Not heard
0.059	48	0.057	0.048	0.105	655	13,600	Not heard
0.068	61	0.032	0.038	0.070	711	18,700	Not heard
0.077	68	0.032	0.032	0.064	740	23,100	Slight whistle
0.094	82	(0.045)	....	....	(d)	....	Loud metallic ring
0.111	87	....	....	....	(d)	....	Loud metallic ring

(d) = detonation registered by pick-up.

measured for various fuels and found to correlate quite well with cetene numbers. Other workers[3] at the time concluded, however, that the measurement of time lags to a fraction of a millisecond was not readily adaptable for routine laboratory evaluation.

In the case of spark ignition, the combustion is more complex, so that it would be surprising if S.I.T. data alone showed any sort of a correlation. Fig. 3 gives some typical S.I.T. data obtained for n-butane by Townend et al[4] some years ago. Due to the technique of preparing samples, detailed information was obtained mostly on the gaseous hydrocarbons. It can be seen that, at low pressures, the S.I.T. falls in a high temperature range, over 500°C.; but at a critical pressure, in this case 1.75-2 atm., the S.I.T. drops to a lower range, 300-400°C. and remains there upon further increase in pressure. This critical zone is exhibited by most compounds except the very stable ones such as methane, benzene, and toluene. It has been explained by the fact that the increased pressure stabilizes the intermediate oxidation products formed. According to these data, then, the S.I.T. decreases with increase in pressure and with increase in F/A ratio, at least in the engine mixture zone. Addition of TEL raises the S.I.T., the effect being less at higher pressures, except within the critical zone (as can be seen from Figs. 3 and 4), when the increase may amount to 150-200°C. The data for isobutane are similar, except that they are at a higher temperature level and the temperature gap in the critical zone is considerably narrowed (see Fig. 4).

Brown[5] determined the maximum rate of rise of pressure, $\frac{dp}{dt}$ in the spark explosion of a number of fuels, and indicated a correlation between knocking tendency and the product of $\frac{dp}{dt}$ with the inverse of the S.I.T. His data for the seven fuels tested are shown in Fig. 5. Some correlation is apparent despite the fact that the working range is very narrow, but it is not understood why he used atmospheric S.I.T. data when he went to the trouble of obtaining explosion pressures.

It might be remarked here that flame speed is not the same thing as combustion speed when we are talking about a particular portion of a single stroke. The correlation between the two for a particular fuel has been shown by Boyd[6] to be as in Fig. 6. In other words, the percentage of the mass burned is less than the volume inflamed, although it speeds up quite rapidly at the end of the stroke. Hence, $\frac{dp}{dt}$ would be a more accurate measurement of heat build-up than flame velocity.

It so happens, however, that very meager data have been published on pressure rise curves of pure fuels, and some (though meager) data do exist on flame speeds for hydrocarbons under

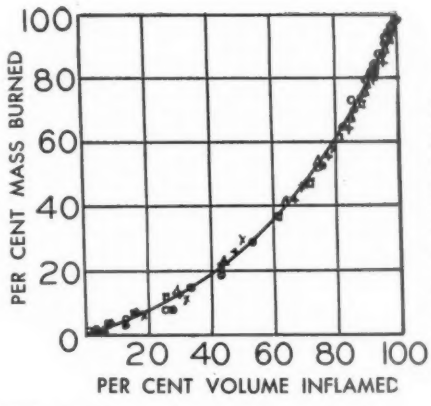


FIG. 6. How volume inflamed relates to mass burned.

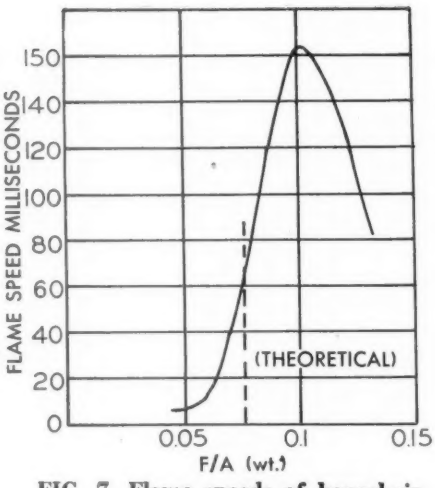


FIG. 7. Flame speeds of benzol-air mixtures at 20 atmospheres gage and 100°C.

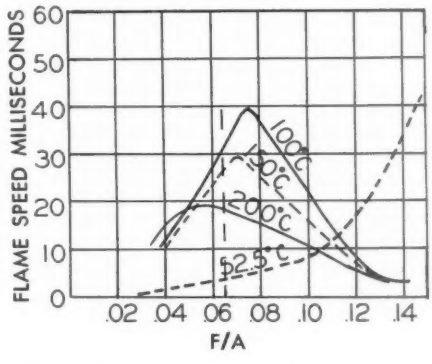


FIG. 8. Flame speeds of gasoline-air mixtures at 20 atmospheres gage.

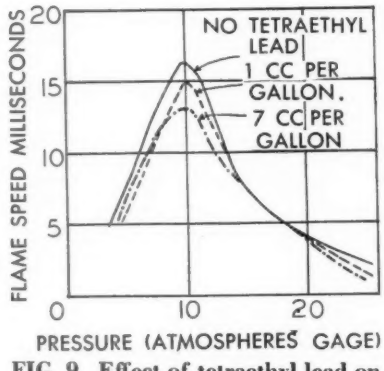


FIG. 9. Effect of tetraethyl lead on flame speed of gasoline-air (0.09 F/A 50°C).

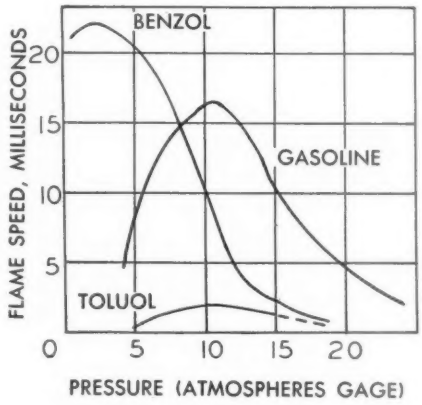


FIG. 10. Flame speeds (0.09 F/A, 50°C) in air.

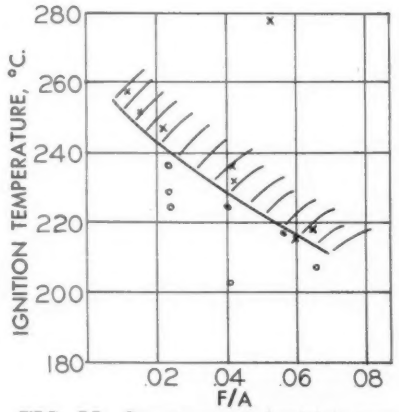


FIG. 11. Spontaneous ignition temperature of N-heptane in air (19.3 atmospheres bomb pressure).

conditions found in the engine. Fig. 7 shows[7] flame speeds of benzol-air mixtures at 20 atm. ga. and 100°C., the maximum speed being somewhat above 0.1 F/A. Fig. 8 shows that initial temperature increase lowers the maximum flame speed and moves the peak to the lean side. In Fig. 9 it is shown that TEL lowers flame speed, the effect being most marked at the maximum speed point, and Fig. 10 shows how the flame speed of benzene differs with pressure in comparison with that of toluene (at 0.09 F/A and 50°C.)

Some rather skimpy laboratory data are also available on the S.I.T. of pure hydrocarbons and blends under engine conditions. The method employed for obtaining the data consisted of weighing out accurately a sample of the fuel to be tested in a sealed glass capsule, which is crushed in a closed system by a plunger and preheated air from a calibrated reservoir is allowed to carry the fuel vapors into the heated calibrated ignition bomb. Ignition is observed by rise in temperature indicated by a fine iron-constatan thermocouple in the center of the bomb. Fig. 11 is illustrative of the technique employed to determine the borderline of ignition at 19.3 atm. ignition bomb pressure. The circles indicate no immediate ignition, and the crosses denote ignition taking place, the line marking the border between the two. Fig. 12 shows the results obtained at 19.3 atm. bomb pressure with an aromatic, isoparaffinic, naphthenic, and paraffinic hydrocarbon. The data for toluene are not very reliable, for the conditions required for the hydrocarbon should really have necessitated a modified apparatus.

As can be seen from Fig. 12, the S.I.T. is essentially a "stability index." The data on the clear fuels are in line with those of Townsend mentioned previously. As to the data obtained on the blends (Fig. 13), they will be discussed later.

Some spark ignition work on a few fuels was published by the British Aeronautical Committee[8] and the information obtained is given in Table 1. These data are plotted in Fig. 14, the sound effects obtained being plotted on a sort of a decibel scale given at the bottom. At F/A ratios of less than 0.07, n-hexane gave the highest pressure, whereas benzene showed the lowest; however, although hexane peaked at this point, benzol continued to give higher pressures at higher F/A ratios, reaching a maximum at about 0.09 F/A. As can be seen at the bottom of the figure, the "knock" or noise intensity increased with F/A ratio for the conditions employed. These "knock" data are compared with various recent trace knock engine data, shown in the center of the figure. In the case of the fuels tested in the CFR Research engine, the peak knock intensity was found at an F/A ratio of about 0.075, which does not appear to line up with the British bomb data. An examination of the supercharged engine curve, however, shows that the trace knock point moves toward the rich side as the pressure level increases. If we assume that the maximum knock curve parallels the trace knock curve, then these data would appear to support those of the British workers.

Fig. 15 shows the pressure-time explosion curves actually obtained in the British work in the case of gasoline-air mixtures at various F/A ratios. It will be noted that as the F/A ratio increases, both the induction time, t, and the explosion time, t_2, become shorter, until knock is encountered. The maximum pressure reached also keeps increasing up to the knock point. The angle (α) of the explosion curve is a good measure of the rate of rise of pressure, and if we assume that the maximum possible theoretical pressure would be reached when the angle is 90 deg., then we should be able to obtain an estimate of the theoretical pressure possible from the different fuels (in the system con-

sidered). Fig. 16 shows a graph of the pressures reached at the various angles and, as the values appear to fall on straight lines, extrapolation to 90 deg. is possible. It can be seen, then, that under the conditions of the tests benzene gives the highest theoretical pressure. At its "knock" point it exerts only 81 per cent of its theoretical pressure, and yet this is above those of other hydrocarbons that exert a higher percentage of their theoretical pressures. TEL would move the knock point up higher toward the theoretical limit.

Some additional spark explosion data for C_8 hydrocarbons obtained by Laure[9] are plotted in Figs. 17 and 18. Initial pressure was apparently 1 atm. It will be observed that although the maxima for pressure and rate of pressure rise were about the same for the hydrocarbons tested, the values differed considerably at given F/A ratios.

In Fig. 19 are plotted, first, the rate of rise of pressure $\frac{dp}{dt_2}$ the maximum pressure reached, and the S.I.T.'s for the various type fuels at various F/A ratios. Unfortunately, the data were obtained in different systems and the hydrocarbons compared are not the same ones, although they are similar in their expected performance. An examination of this series of curves will show that there appear to be three main competitive factors that are responsible for knock-free power.

These are given as follows:

Factors determining knock-free power

	Determines	Measured by	Determined by
I. Energy characteristics 1. Maximum pressure (due to maximum temperature and volume ratio)	Power level	Maximum pressure	Composition
2. Rate of combustion	Rate of heat build up in unburned portion	Rate of pressure rise	Composition (and structure)
II. Knock characteristic Stability	Point of spontaneous ignition of unburned portion	S. I. T.	Structure

This competitive system results in a median effect that can be termed as knock-free power. It is really a race between the energy input into the unburned portion of the charge and the amount of energy that the latter can store without "blowing up." These factors appear to be sufficiently independent to require individual determination for proper evaluation of the fuel.

Fig. 20 is a rough representation of these three factors for three classes of fuels: (1) Aromatic, (2) naphthenic, and (3) paraffinic, plotted against F/A ratio. The reciprocal of $\frac{dp}{dt}$ is given, for knock-free power is favored by slower combustion rate, and hence slower rate of heat build-up in the unburned portion. The aromatics give less pressure than other hydrocarbons in the lean mixtures and higher pressure in the rich. The naphthenes appear to give the highest pressure in the lean range and the lowest in the rich, whereas the paraffins are intermediate between the two. As to the reciprocal of rate of pressure rise, the paraffins appear to show the highest rate, and the aromatics show the lowest, the naphthenes being in between. With respect to S.I.T., the aromatics are by far the most resistant, whereas the paraffins are least resistant; however, the aromatics show a much greater drop in S.I.T. as the mixture becomes richer.

As stated previously, it is unfortunate that more data are unavailable on these characteristics for pure hydrocarbons at engine conditions. This is particularly so in the case of isooctane, in which case if such data were available it would be possible to obtain a comparative index with respect to other hydrocarbons, as in the case of octane number determinations. This would also enable one to determine the relative importance of each of the three characteristics with respect to each other. The meagerness of the data is particularly surprising when we note how much research work and

FIG. 12. Spontaneous ignition temperature of hydrocarbons (19.3 atmospheres pressure).

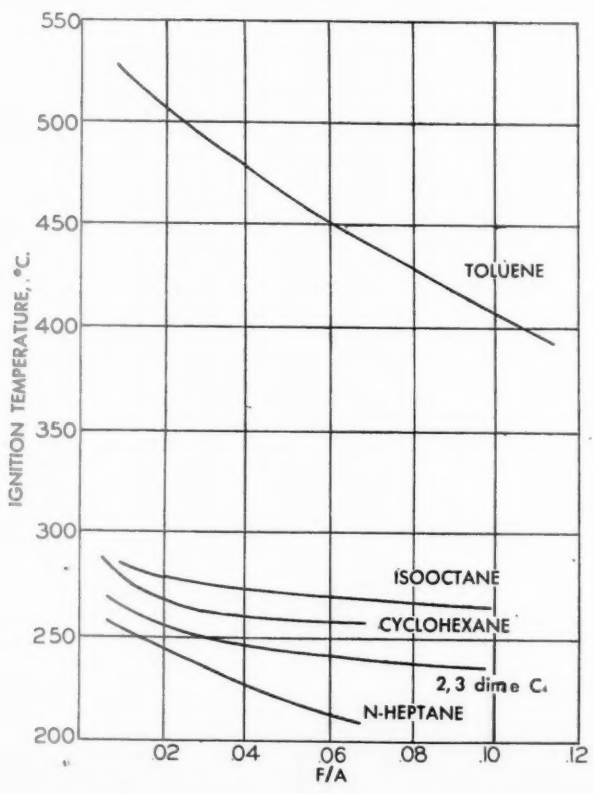
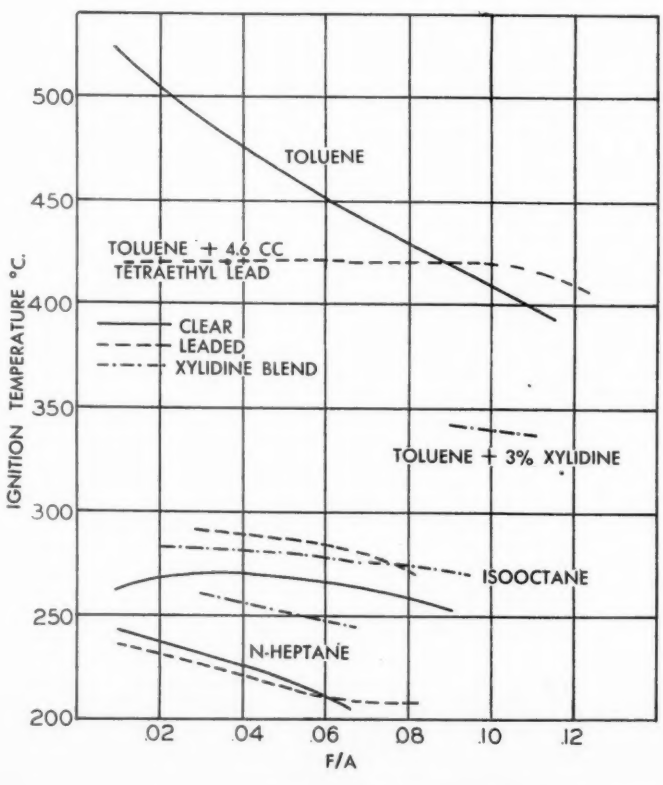


FIG. 13. Spontaneous ignition temperatures blends (19.3 atmospheres pressure).



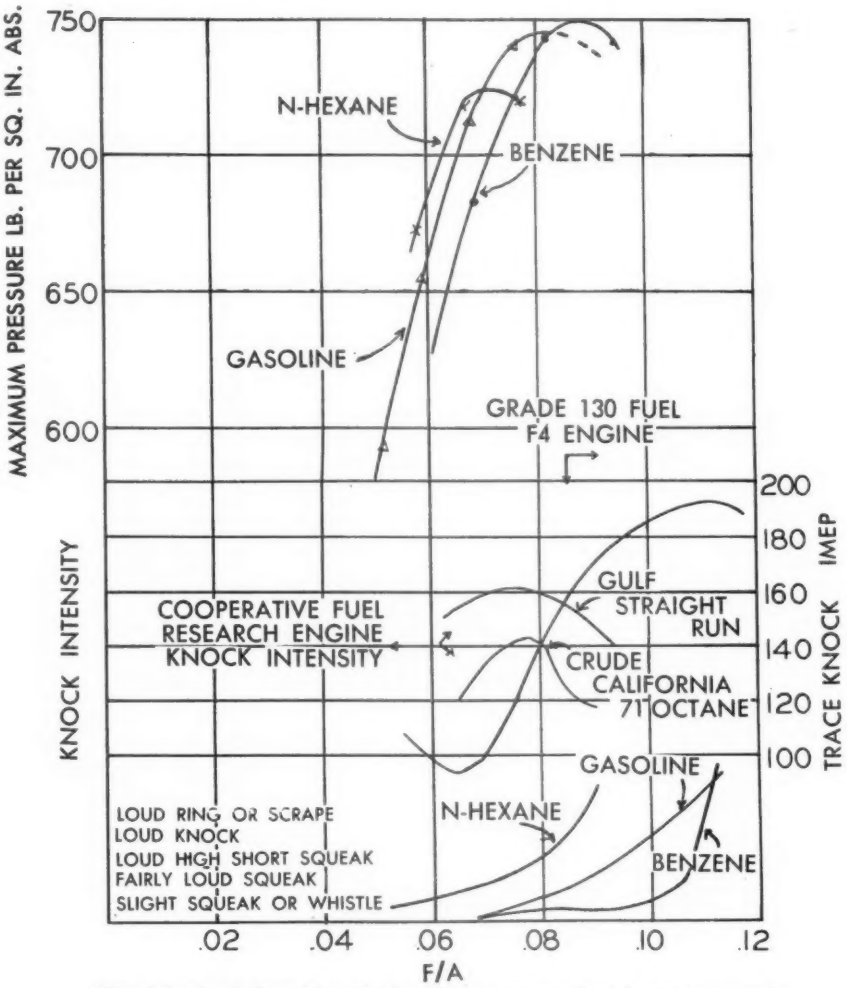


FIG. 14. Static bomb explosion data compared with engine results.

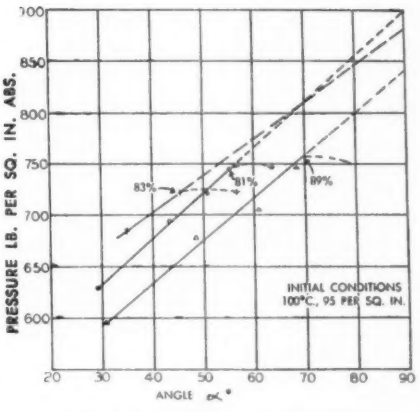


FIG. 16. Estimated theoretical pressures.

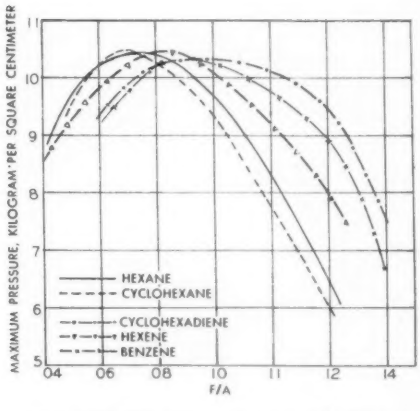
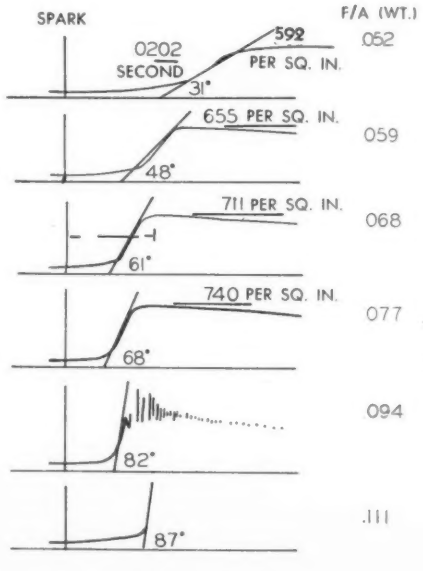


FIG. 17. Maximum pressures during explosion C_6 hydrocarbons in air.

money has already been spent on the subject of combustion.

On the basis of these considerations, then, the ideal gasoline would be one of high energy level, low rate of heat build-up, high S.I.T., and flat S.I.T. slope vs. F/A ratio.

FIG. 15. Gasoline-air explosion records.



It would be logical to ask just where inlet temperature fits into the picture. To obtain an answer to this, reference can be made to other data obtained by the British Aeronautical Committee, shown in Table 2, giving maximum pressures at the same F/A for gasoline and benzene at two inlet temperatures (100°C. and 200°C.) It will be noted that knock is *not* considered at all here. The figures show that an increase in inlet temperature reduces the maximum pressure, and that the reduction is greater in the case of aromatics. Hence, loss of power by increase of inlet temperature need not be attributed entirely to knock.

The S.I.T. data on antiknock blends given in Fig. 13 are quite interesting. It will be observed that xylidine raises the S.I.T. of heptane considerably, that of isooctane less, and actually lowers the

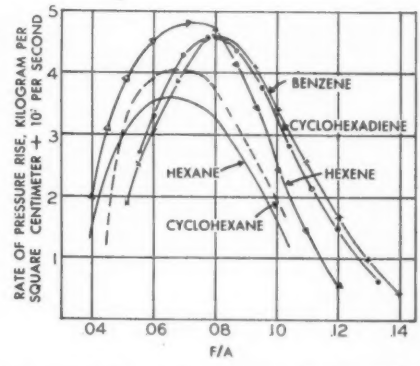


FIG. 18. Rate of pressure rise in explosions of C_6 hydrocarbons in air.

TABLE 2

Effect of intake air temperature on maximum pressure.

Initial temperature, °C.	Initial pressure, lb. per sq. in. abs.	Pressure rise, lb. per sq. in.			
		Air-gasoline, 11 per cent rich	Per cent decrease	Air-benzene, 10 per cent rich	Per cent decrease
100	50	321	....	327	....
200	50	250	22.1	248	24.2
100	100	660	....	680	....
200	100	519	21.3	523	23.1
			0.8		1.1

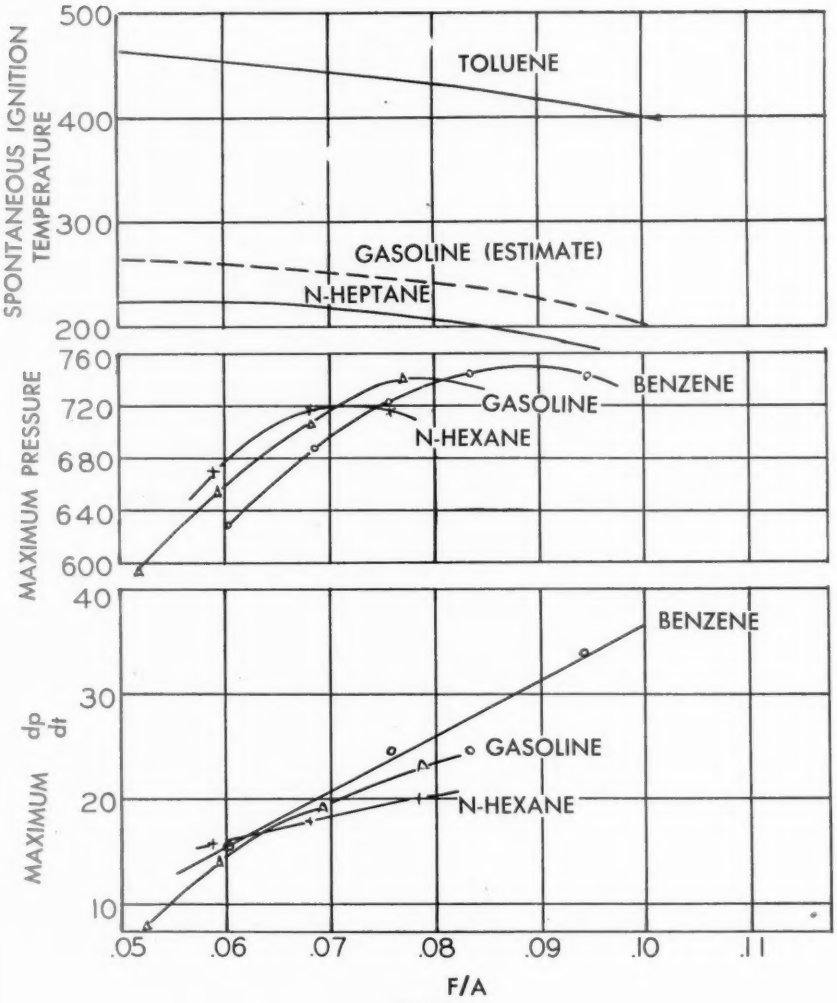


FIG. 19

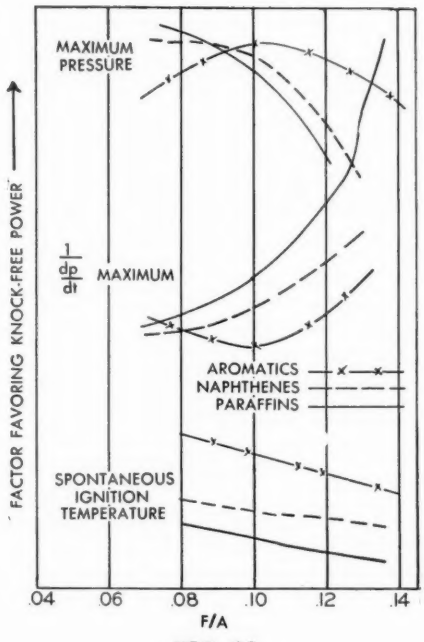


FIG. 20

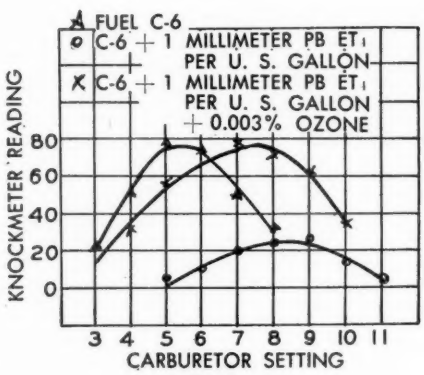


FIG. 21

S.I.T. of toluene some 60°C. TEL, on the other hand, appears to somewhat lower the S.I.T. of heptane in the lean end and raise it somewhat in rich mixtures. It raises the S.I.T. of isooctane in all ratios, and affects toluene in the same way as heptane, but more so. Of course TEL is a fairly unstable substance. Its S.I.T. is about 150°C., and addition to a fuel of 300°C. S.I.T. (at atm. press.) raises the S.I.T. to a peak of 430°C. at 15 per cent concentration[10]. TEL, as such, is ineffective as an antiknock. Only in its decomposed state is it effective[11]. Apparently the effect is due to lead atoms rather than the organic groups. Proknocks lower the S.I.T.

The xylidine results might be explained on the basis of stability of the compound. P-xylidine decomposes appreciably under its own pressure at 318°C., so one would expect it to decompose more and more as the temperature level is increased.

Some apparently unexplainable data obtained by Brooks[12] are shown in Fig. 21. The leaded fuel was found to go through a peak knock point at a richer F/A ratio than the clear fuel. When ozone was added to counteract the effect of the TEL, the knock intensity was brought back to that of the clear fuel, but the peak point was at an F/A ratio intermediate between those of the other fuels.

A possible explanation of the results is indicated in Fig. 22. As the maximum pressure would be unaffected by the small amount of dope, the only factors remaining that would be affected are burning rate and S.I.T. If we assume that TEL would lower the burning rate more at the peak point (as in Fig. 9) and the ozone brought it back to that of the clear fuel, and that the effect of TEL on S.I.T. is as shown (Cf. Fig. 13), while the ozone reduced the S.I.T. as shown, then the knock intensity could be estimated to correspond to the upper curves in Fig. 22. which are similar to those given by Brooks.

● **Acknowledgment.** Acknowledgment is hereby given to the Standard Oil Development Company for permission to publish the data on spontaneous ignition temperatures of some pure hydrocarbons and blends.

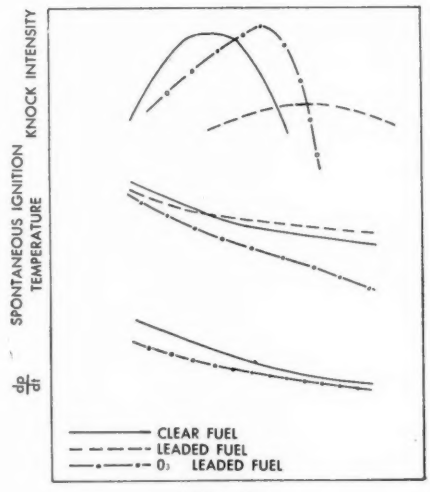


FIG. 22

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★ ★ ★

Conversion graph for open flows of gas wells

By **W. F. MARTIN,** Texoma Natural Gas Company

EXCLUSIVE

THE records of many natural gas companies are on a pressure base of 16.4 lb. per sq. in. and the open flow curves based on field tests are therefore on this same pressure base. The Railroad Commission of Texas requires all reported natural gas to be on a pressure base of 14.65 lb. per sq. in. Therefore, there are many conversions to make before a Railroad Commission report can be filed.

The Interstate Oil Compact Commission at a recent meeting at Grand Rapids, Michigan, recommended a uniform pressure base of 14.65 lb. per sq. in. for reporting natural gas production to all state conservation departments. At present the recommended pressure base is required by law in Texas and Arkansas, but all states that are members of the Compact Commission have been requested to adopt the uniform method.

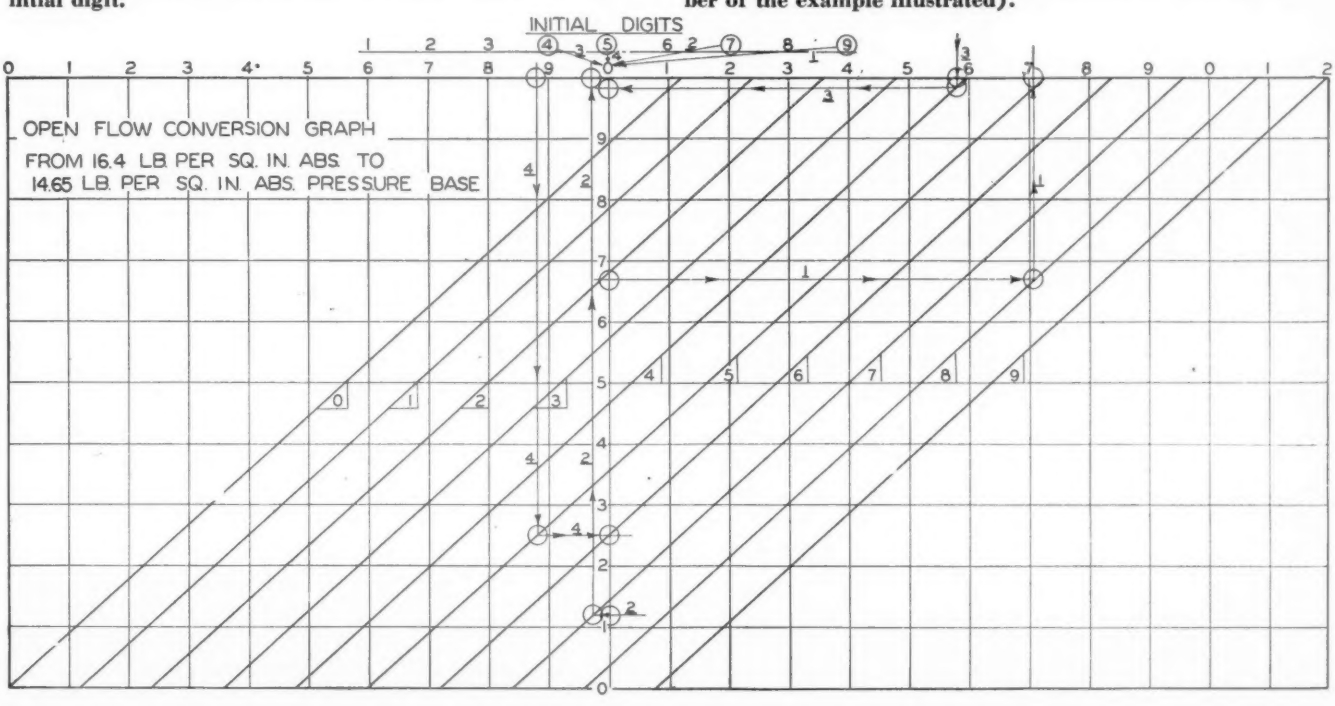
Conversion of the open flow of a gas well for pressure base can be made quickly by means of a slide rule or a conventional graph, but the difficulty with this computation is that it is not possible to read enough places accurately on the slide rule or conventional graph, and such conversions therefore, must be made by means of a calculating machine for the required accuracy. If, however, a graph could be prepared which would permit the reading of converted open flow to the nearest 10 M. cu. ft., it would facilitate the work of conversion and meet the required accuracy. The writer, therefore, has undertaken to construct a graph to accomplish this purpose.

Referring to the graph, it will be observed that it is on coordinate paper with ten parallel curve lines drawn thereon. At the top of this graph is a series of nine numerals that are known as initial digits, and it is indicated that these digits are to be used instead of the zero just above the top of the numbered vertical scale, the digit to be used being dependent upon the initial digit of the open flow to be converted. The curve lines are numbered from zero to nine and the use of these lines is indicated by the initial digit of the open flow to be converted. To ascertain the point to be used on the vertical scale to make the conversion, disregard the initial digit of the open flow, using the last digits only. Where the point on the vertical scale intersects the proper curve line, read converted open flow on the horizontal scale, using the proper initial digit. For instance, if the open flow on a 16.4 lb. pressure base were 8670 M. cu. ft., we would use 670 as the point on the vertical scale. Where this point intersects the eight curve line we would read the converted open flow on the horizontal scale, using as the initial digit eight plus one, or nine. In all cases, (from a pressure base of 16.4 lb. to a pressure base of 14.65 lb.), the initial digit is the initial digit of the open flow undergoing conversion plus one. It will be observed that these curve lines cross, in most cases, the numbered vertical scale. If the initial digit were nine and the reading is taken to the left of the numbered vertical scale, the initial digit for the converted open flow would of course be eight, or nine minus one, for the reading is on the minus side of the vertical scale.

This special graph construction permits a reading of four places rather than three, which is impossible with the conventional graph. At first glance, the graph may appear to be complicated, but in reality it is quite simple. The only things to bear in mind when converting from 16.4 lb. pressure base to 14.65 lb. pressure base, are that the curve line to

Example: **Convert 8,670,000 cu. ft. from a 16.4 lb. pressure base to a pressure base of 14.65 lb. per sq. in. abs.**
Procedure: **Use last three digits (670) (Follow arrows labeled 1). Read converted open flow on horizontal scale where 670 on vertical scale intersects the "8" curve, using "9" as the intial digit.**

Explanation of initial digits: **The initial digit, used where indicated, is always one more than initial digit of the number being converted. (16.4 lb. to 14.65 lb.)**
Solution: **8670 M. cu. ft. at 16.4 lb. = 9710 M. cu. ft. at 14.65 lb. (approximately). (Numbers on arrows indicate the number of the example illustrated).**



be used is the line bearing the number corresponding to the initial digit of the open flow undergoing conversion and that the initial digit to be used in connection with the horizontal scale where indicated is the initial digit of the open flow undergoing conversion plus one.

To further clarify this graph, four examples are given.

Example No. 1:

Open flow on a 16.4 lb pressure base —8670 M. cu. ft.

Required: Open flow on a 14.65 lb. pressure base.

Procedure: Drop the initial digit of the open flow, which leaves 670. Follow the 670 line on the vertical scale to the eight curve line and read open flow on a 14.65 lb. pressure base on the horizontal scale, using nine as the initial digit on the horizontal scale. It will be noted that the converted open flow is 9706 or to the nearest ten, 9710 M. cu. ft. If we had a graph ten times the size of the one shown, we would be using the ninth major section of this graph, hence the nine is the initial digit.

Example No. 2:

Open flow on 16.4 lb. pressure base—7120 M. cu. ft.

Required: Open flow on a 14.65 lb. pressure base.

Procedure: Drop the initial digit of the open flow. Read on the horizontal scale, using eight as the initial digit, open flow on a 14.65 lb. pressure base where 120 on the vertical scale intersects the seven curve line. It will be noted that this reading is to the left of the numbered vertical scale and that the reading will be 7970 M. cu. ft. This simply means that since the reading is to the left of the eighth section of a large graph it will of course be read in the seventh section and the initial digit of the converted open flow will therefore be seven.

In the event a conversion from 14.65 lb. pressure base to 16.4 lb. pressure base is required, the procedure would be as follows:

Use the last three digits to obtain point on the horizontal scale. The curve line to be used, if used to the right of numbered vertical scale, will be the initial digit of the open flow minus one; if to the left of the vertical scale, it will be the same as the initial digit of the open flow. The number of the curve line used will be the initial digit of the converted open flow. For instance, if the open flow on a 14.65 lb. pressure base were 5580, the point on the horizontal scale would be 580. Where this point intersects the four curve line, read converted open flow on the vertical scale, using four as the initial digit.

If, however, the open flow on a 14.65 lb. pressure base were 5880, it would be found that the point 880 would not intersect the four curve line to the right of vertical scale. It would then be necessary to move to the point 880 to the left of vertical scale and take reading at its intersection with the five curve line. The reading on the vertical scale for the converted open flow would then have five for its initial digit.

Example No. 3:

Open flow on a 14.65 lb. pressure base —5580 M. cu. ft.

Required: Open flow on a 16.4 lb. pressure base.

Procedure: Drop initial digit of open flow. Read 580 on horizontal scale to the right of vertical scale. Where this point intersects the four curve line, read on vertical scale the converted open flow using four as the initial digit. It will be observed that this reading is 4980 M. cu. ft. on a 16.4 lb. pressure base. When reversing the conversion (14.65 lb. to 16.4 lb.), the initial digit on the vertical scale will be one less than the initial digit of the open flow undergoing conversion, if the reading is to the right of the vertical scale.

Example No. 4:

Open flow on a 14.65 lb. pressure base—5880 M. cu. ft.

Required: Open flow on a 16.4 lb. pressure base.

Procedure: Drop initial digit of open flow. Read 880 on horizontal scale to the left of vertical scale. Where this point intersects the five curve line, read on vertical scale the converted open flow, using five as the initial digit. It will be observed that this reading is 5250 M. cu. ft. on a 16.4 lb. pressure base. When converting from 14.65 lb. to 16.4 lb., the initial digit on the vertical scale will be the same as the initial digit of the open flow undergoing conversion, if reading is to the left of the vertical scale.

It will be noted that this particular graph is designed for open flow under 10,000,000 cu. ft.; however, similar graphs can be made for other open flow ranges.

It is possible, however, to convert open flows that range higher than 10,000,000 cu. ft. by taking two readings and taking the sum thereof. Example follows:

Open flow on a 16.4 lb. pressure base —22,670 M. cu. ft.

Required: Open flow on a 14.65 lb. pressure base.

Procedure: Take reading on horizontal scale at the intersection of 670 on vertical scale and the two curve. This reading is 2990. Take reading on the horizontal scale at the intersection of zero on the vertical scale and the two curve. This reading is 2239, or 22,390. 22,390+2990=25,380. 22670×1.11945 = 25,378, or to the nearest 10 M. cu. ft., 25,380.

It will be noted from the above that 2670 is first treated as a unit; the next treatment is of 2000 as a unit.

2670×1.11945= 2988.9
2000×1.11945=2238.9 × 10=22389.0

Total 25377.9

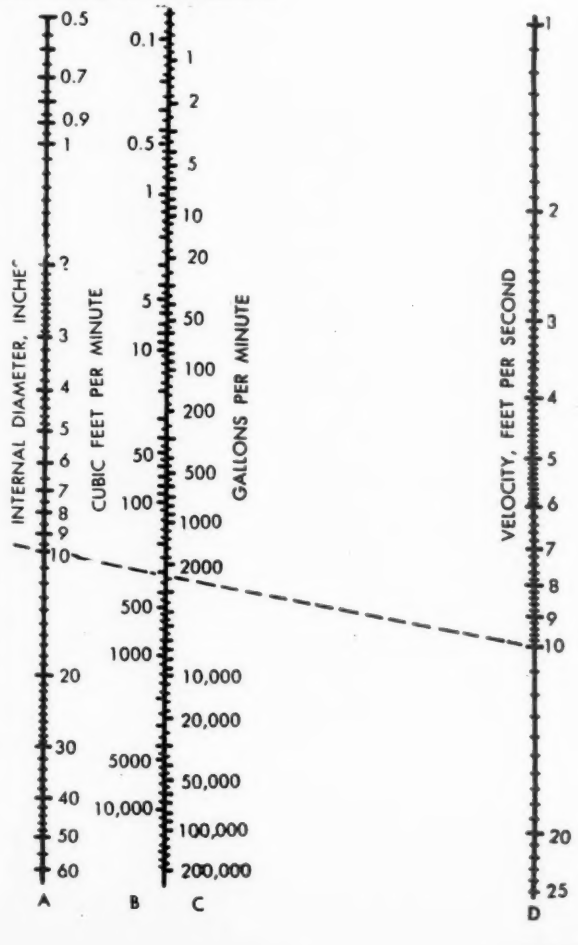
It is believed that this graph provides a fast and accurate method of ascertaining conversions of open flow, for they can be read to the nearest 10 from their respective curves. ★★★

Practical water flow chart

By
W. F. SCHAPHORST

A PROMINENT water flow specialist asked me to prepare this chart in such a way that it would include all the ordinary diameters from 0.5 in. to 60 in., column A, and water velocities up to and including 25 ft. per second, column D. It is therefore a decidedly practical chart as the problems most commonly met are solved by simply running a straight line across and through the two known points in columns A and D.

For example, the dotted line drawn across this chart shows that if the internal diameter of the pipe is 10 in., column A, and the velocity of the water is 10 ft. per second, column D, the flow of the water through the pipe amounts to nearly 2500 gal. per minute, column C, which is equivalent to nearly 325 cu. ft. per minute, column B. ★★



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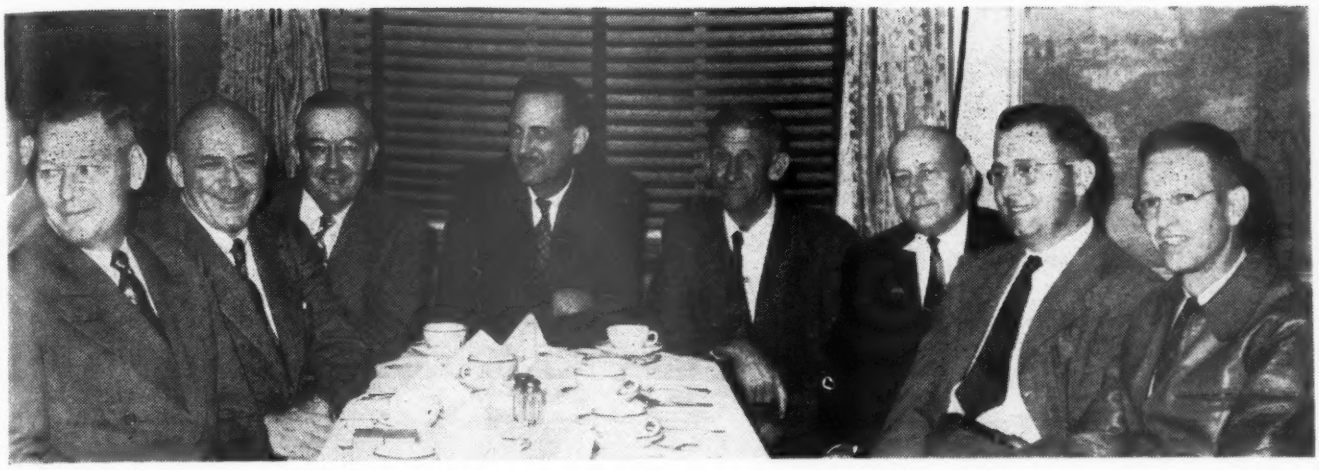


A portion of the company officials and guests attending the dedication ceremonies at the terminal are shown left to right: H. L. Holland, L. T. White, H. W. Kendall, J. H. Mobley, "Preacher" Pierce, E. F. Brakefield, E. P. Krumbholz, and C. J. Raley.

Arkansas Fuel Oil Company dedicates new gasoline terminal at Nashville

By **DON ATTAWAY**
Arkansas Fuel Oil Company

EXCLUSIVE

More than 150 customers, friends, city dignitaries, and company officials attended the dedication ceremonies of the Arkansas Fuel Oil Company's newest and most modern distribution plant, the Cumberland River Terminal, situated in the heart of historic Nashville, Tennessee.

The guests were invited to the new terminal to inspect the modern facilities installed and to view the giant storage tanks, loading racks, and warehouse. Of special interest was the unusually designed unloading barge situated on the Cumberland River, as well as the unique

Interior view of the storage area with the 40,000-bbl. tank shown to the left and the two 20,000-bbl. tanks to the right. Concrete fire wall is in rear.

Photos by
J. E. HAMPSON

An airplane view of the new six-acre terminal showing location of storage facilities and warehouse.

installation of machinery and equipment employed to receive and distribute petroleum products.

Mayor Thomas L. Cummings of Nashville delivered the speech of welcome to the Arkansas Fuel Oil Company representatives in which he stated that this new operation was a definite asset and worthy addition to the commercial area of the Tennessee capital.

Immediately after an inspection tour of the terminal more than 60 guests attended a buffet supper held in the Andrew Jackson Room of that hotel in Nashville. Here an address was made by George C. Keller, public relations director for the Lake Charles Refining Corporation. He explained the numerous operations of this plant refinery and detailed the variety of products made available to the Cumberland River Terminal. He also showed a color film of the refinery and stated that the distance by barge from Lake Charles to the new terminal was 1280 miles and that an average river tow required from 25 to 30 days for the trip.

H. L. Holland, manager of distributor sales for the Arkansas Fuel Oil Company, made an interesting talk on the future plans of the company. Alf Levine, head of the Tennessee Oil Men's Association, also made a brief but informative talk.

The principal address of the evening was made by L. T. White, director of sales promotion of Petroleum Advisers, Inc., New York, who discussed the anticipated progress of the oil industry and reviewed the vast field of new products that have been, and are now being, developed.

The Cumberland River Terminal is the first of seven proposed plants to be installed and operated by the Arkansas Fuel Oil Company as part of its postwar expansion program. At the present time the company is operating terminals at Houston, Texas; Mobile, Alabama; Panama City, Florida; Savannah, Georgia, and Wilmington, Delaware.

This newest terminal is in the center of Nashville, Tennessee, and only two city blocks from the most traveled bridge over the Cumberland River. It covers approximately six acres and is quickly accessible to the metroplitan district of Nashville.

Storage capacity of the terminal is 4,200,000 gal. and consists of one 40,000-bbl. tank that carries house-brand gasoline, one 20,000-bbl. tank for premium gasoline, and two 20,000-bbl. tanks for kerosine and heating oil. There are also five 20,000-gal. horizontal tanks that are used for auxiliary products such as lube oil, cleaning solvent, anti-freeze, etc.

Two of the listed storage tanks are equipped with Horton floating roofs and each tank is painted bright aluminum with the Cities Service emblem in black. These tanks are flooded at night with powerful lights mounted near the tanks.

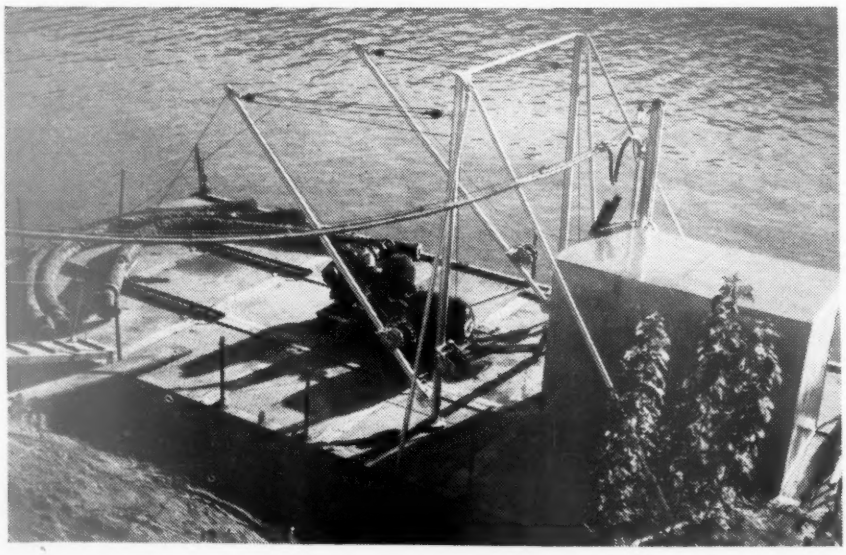
The four main tanks are enclosed by a concrete wall some 7 to 9 ft. high.

The terminal warehouse, painted white with green trim and green roof, measures 60 ft. by 140 ft. and has a portion devoted to office space but the larger part of the building is used for storage of merchandise. To the rear of the warehouse on a railway siding is a convenient five-spot loading rack and to the front of the building is a well-equipped tank truck loading rack.

The operation of the terminal will be under direction of John H. Mobley, manager of all Arkansas Fuel Oil Company terminals and the personnel will consist of Charles J. Raley, Jr., terminal operator; John R. Renison, assistant; H. W. Darris, clerk; G. H. Martin and C. C. Fueler, loaders.

★ ★ ★

View of unloading barge on Cumberland River.



Evaluation of absorber operating efficiency*

By **E. G. RAGATZ,**
Consulting Engineer
and
J. A. RICHARDSON
Process Engineer
Bechtel Brothers McCone Company

PART 1

● **Summary.** *Although it has been of invaluable aid to the industry, the conventional theoretical absorption tray analysis of Kremser and Brown presents a serious weakness in that its basic "tray efficiency" factor shifts markedly in value with percentage of key component recovered. Furthermore, the degree of this shifting varies widely for different columns, and for different conditions of operation of a given column. As it is rarely possible to operate a commercial column under an exact pre-set condition of feed quality, column loading, and key component recovery, this shifting of the tray efficiency drastically limits the usefulness of the conventional analysis for accurate specification definition, or for precise column operation comparison.*

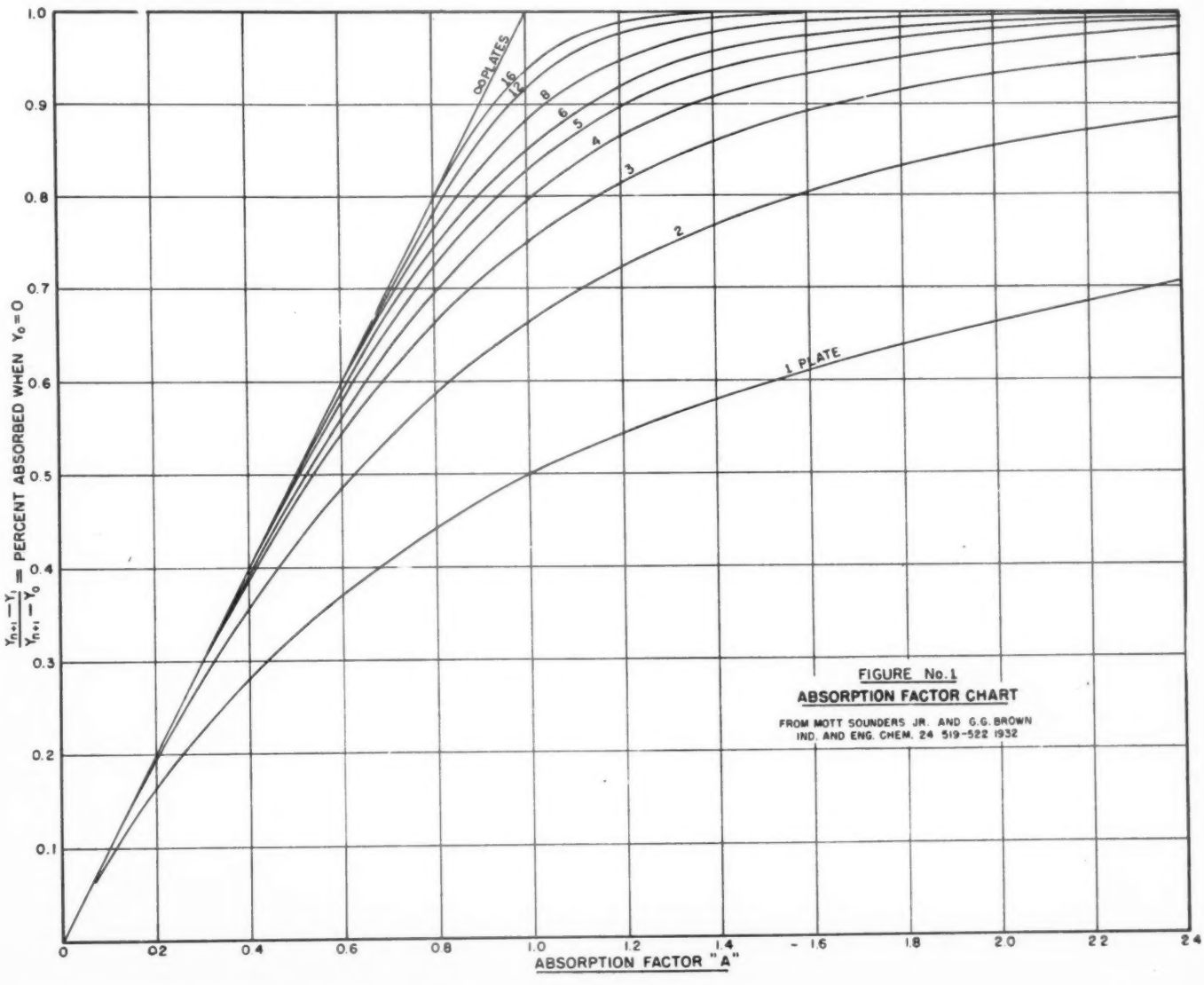
The authors have recently analyzed the operating characteristics of some 40 commercial columns ranging in pressure from 35-lb. to 1800-lb. gauge. From this study they have developed a technique for evaluating absorber performance that utilizes an experimentally derived absorption factor chart in place of the classical Brown chart, and which gives promise of fully correcting the limitations of the conventional theoretical method.

*Presented before California Natural Gasoline Association, October 11, 1946.

To date almost all industry evaluations of absorber operating efficiencies have been based on the classical absorption factor chart of Souders and Brown[1] (Fig. 1). This chart was developed from the original work of Kremser[2], and shows the relationship existing between per cent component recovery, number of theoretical trays employed, and absorp-

1. Souders Mott., Jr., and Brown, G. G., *Ind. Eng. Chem.*, 24, 519 (1932).
2. Kremser, A., *Proc. Calif. Natural Gasoline Assoc.*, 5, No. 2 (1930).

FIG. 1. Absorption factor chart.



Ed Ragatz left the University of California in 1917 to join the air corps. Finished his formal education at M.I.T. in 1921. Joined the Union Oil Company and for 18 years was identified with many important process developments in the natural gasoline and solvent treating fields and has published many technical articles on these subjects. In 1939 was made manager of the economics department and in 1942 left the petroleum field to assist in the rapid war-work expansion of a specialty machine tool company, which he had previously founded with two associates.

Ragatz accepted an assignment with Bechtel-McCone-Parsons in 1944 as liaison engineer on a large war-time project at the C.P.I.M. refinery at Curacao—involving extensive air commuting between Curacao and New York. For the last year he has headed the natural gasoline division, Bechtel Brothers McCone Company.

tion factor "A", for an ideal absorber—i.e., an absorber wherein perfect equilibrium is achieved on each tray, and for which the values of oil and gas rate, temperature, and pressure are constants throughout the column for any one given operation.

The absorption factor "A" of this chart can best be defined as:

The ratio of the amount of a given component absorbed on a tray to the amount of that same component absorbed on the immediate tray above.

By mathematical analysis, Souders and Brown have shown that for the ideal column:

$$A = \frac{y_{n+1} - y_n}{y_n - y_{n-1}} = \frac{L}{V} \times \frac{1}{K}$$

Where:

L = total moles of liquid flowing between trays,

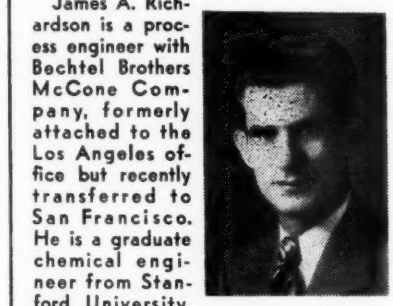
V = total moles of gas flowing between trays,

x = mole fraction of a component in the liquid,

y = mole fraction of a component in the gas,

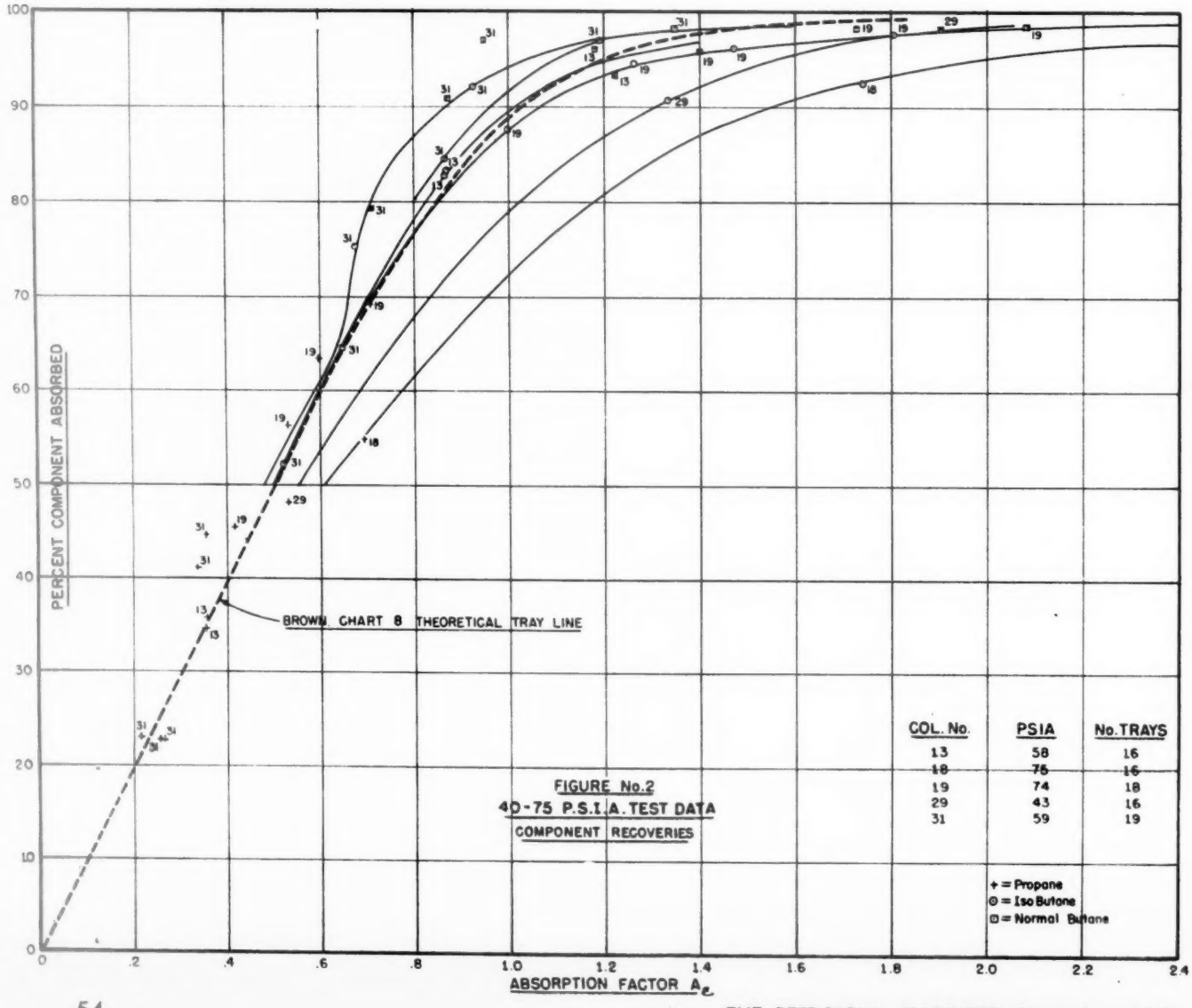
$K = \frac{y}{x}$ = vapor-liquid equilibrium constant (a function of temperature and total pressure for each component), and,

n = number of plate, beginning at the top plate of the absorber (when used as a subscript indicates plate of origin from which the liquid overflows or the vapor rises).



James A. Richardson is a process engineer with Bechtel Brothers McCone Company, formerly attached to the Los Angeles office but recently transferred to San Francisco. He is a graduate chemical engineer from Stanford University, with post graduate work at the Missouri School of Mines. Since 1942 he has specialized in process design and development work for Phillips Petroleum Company at Bartlesville, Oklahoma, and Bechtel Brothers McCone Company.

FIG. 2. 40-75 lb. per sq. in. abs. test data. Component recoveries.


PERCENT COMPONENT ABSORBED
ABSORPTION FACTOR Ae
BROWN CHART 8 THEORETICAL TRAY LINE
FIGURE No.2
40-75 P.S.I.A. TEST DATA
COMPONENT RECOVERIES
COL. No. | PSIA | No. TRAYS
13 | 58 | 16
18 | 75 | 16
19 | 74 | 18
29 | 43 | 16
31 | 59 | 19
+ = Propane
⊙ = Iso Butane
□ = Normal Butane

Although entirely theoretical in development, the Brown chart emphasizes an extremely vital operating characteristic of all absorbers, namely:

Once a relatively small number of trays is provided, the use of additional trays in the column is materially effective over only a limited range of absorption factor values.

The reason for this limitation, of course, is inherit in the basic definition of absorption factor, for obviously, practical limits of recovery are reached with the use of only a few trays whenever the ratio of the amount of a given component absorbed on a tray to that absorbed on the tray above is substantially smaller, or larger, than 1.0.

For the narrow absorption factor range of some 0.8 to 2.0, however, both the number and absolute efficiency of the column trays are of exceeding importance, for it is over this range that the basic design of the column, with its accompanying oil circulation requirement, is developed. Effective handling of the commercial absorption column problem calls for the precise relating of the actual column trays employed with the lean oil rates and quality, column operating temperatures and pressure, and resultant key component recoveries, over this particular absorption factor range.

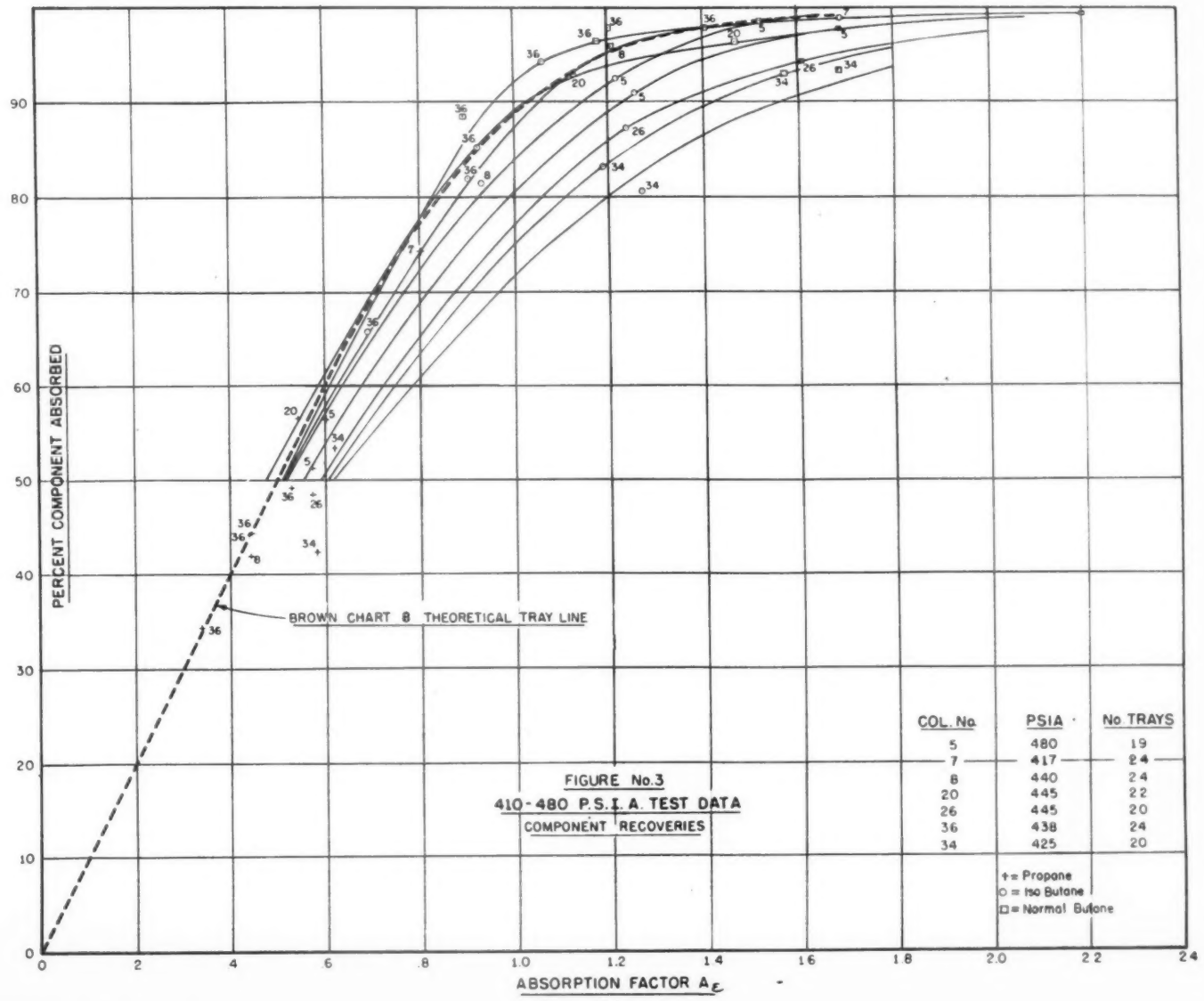
From its inception, the theoretical tray analysis recognized that the physical values of $\frac{L}{V}$ and K vary substantially through an actual column; that such variations correspondingly affect the true value of "A"; and that those variations increase rapidly with increasing pressure. It was long assumed, however, that an effective or mean "A" factor could be developed that would average out these differences, and that through such a mean factor, the operation of an actual column could be directly related to a parallel-operating theoretical column.

If this assumption had proved correct, solution of the absorber problem would have been simple, for under such circumstances relative key component recoveries could have been accurately predicted by relating an appropriate "A" factor to its corresponding component recovery value through the proper theoretical tray line on the Brown chart. Furthermore, an exact measure of the operating efficiency of the actual column would have been expressed in the ratio of the number of trays required for the parallel-operating theoretical column to those utilized in the actual column.

Unfortunately, experience has shown that no such simple relationship exists between an actual column operation and a parallel-operating theoretical unit. Instead, it has been found that the number of theoretical trays required to match the operation of an actual column shifts markedly with the percentage of key component recovered, and that the degree of this shifting varies widely for different columns.

As a consequence, the conditions of operation of an actual column must be exactly specified (and met) if a theoretical tray efficiency factor is to be used for measuring accurately a column's

FIG. 3. 410-480 lb. per sq. in. abs. test data. Component recoveries.


PERCENT COMPONENT ABSORBED
ABSORPTION FACTOR A_ε
BROWN CHART 8 THEORETICAL TRAY LINE
FIGURE No.3
410-480 P.S.I.A. TEST DATA
COMPONENT RECOVERIES
COL. No. | PSIA | No TRAYS
5 | 480 | 19
7 | 417 | 24
8 | 440 | 24
20 | 445 | 22
26 | 445 | 20
36 | 438 | 24
34 | 425 | 20
+ = Propane
○ = Iso Butane
□ = Normal Butane

relative operating effectiveness. As it is rarely possible to operate a commercial column under such pre-designated operating conditions, the conventional theoretical "tray efficiency" method can rarely be used for accurate specification definition, or for precise operating column comparison.

In seeking an improvement on the conventional absorber evaluation method, the authors concluded that continued use of a mean absorption factor offered the best means for correlating the major variables associated with the absorber operation; that the embodiment of this factor in a relative component recovery chart offered the simplest approach to absorber efficiency evaluation; and that the key to the evaluation problem's solution lies in substituting correlating factors derived from actual operating data for the older theoretically calculated factors.

Following this line of reasoning, an intensive study was made of a large number of tests from some 40 different columns ranging in operating pressure from 35-lb. to 1800-lb. gauge. As a result of this study, an analytical method has been developed that gives promise of having the following desirable absorber evaluation characteristics:

1. Utilizes simple data readily obtainable from presently installed commercial columns.
2. Eliminates the need for exercise of personal judgment in analyzing these data.
3. Provides an automatic check on the consistency of the test-indicated key component recoveries.
4. Predicts relative key component recoveries well within the accuracy required for precise engineering work.
5. Accurately establishes the operating efficiency of an absorber without the need of running on a precise quality of feed stock, or effecting a precise recovery of a given key component.
6. Is capable of accurate definition, and utilizes a simple number for final identification of the column's operating efficiency.

The first step of our operating data analysis required the selection of a sound basis for calculating the mean absorption factor. Fortunately, this particular task had already been adequately handled by Edmister[3] in his recent analysis of Horton and Franklin's[4] proposed absorption calculation method. Edmister's mean absorption factor is based on the "A" factors existing at the top and bottom of the column, and may be expressed as:

$$A_e = \sqrt{A_B\,(A_T + 1)} \div 0.25 - 0.5$$

Where:

A_e = effective or mean absorption factor,

A_B = absorption factor at bottom tray conditions,

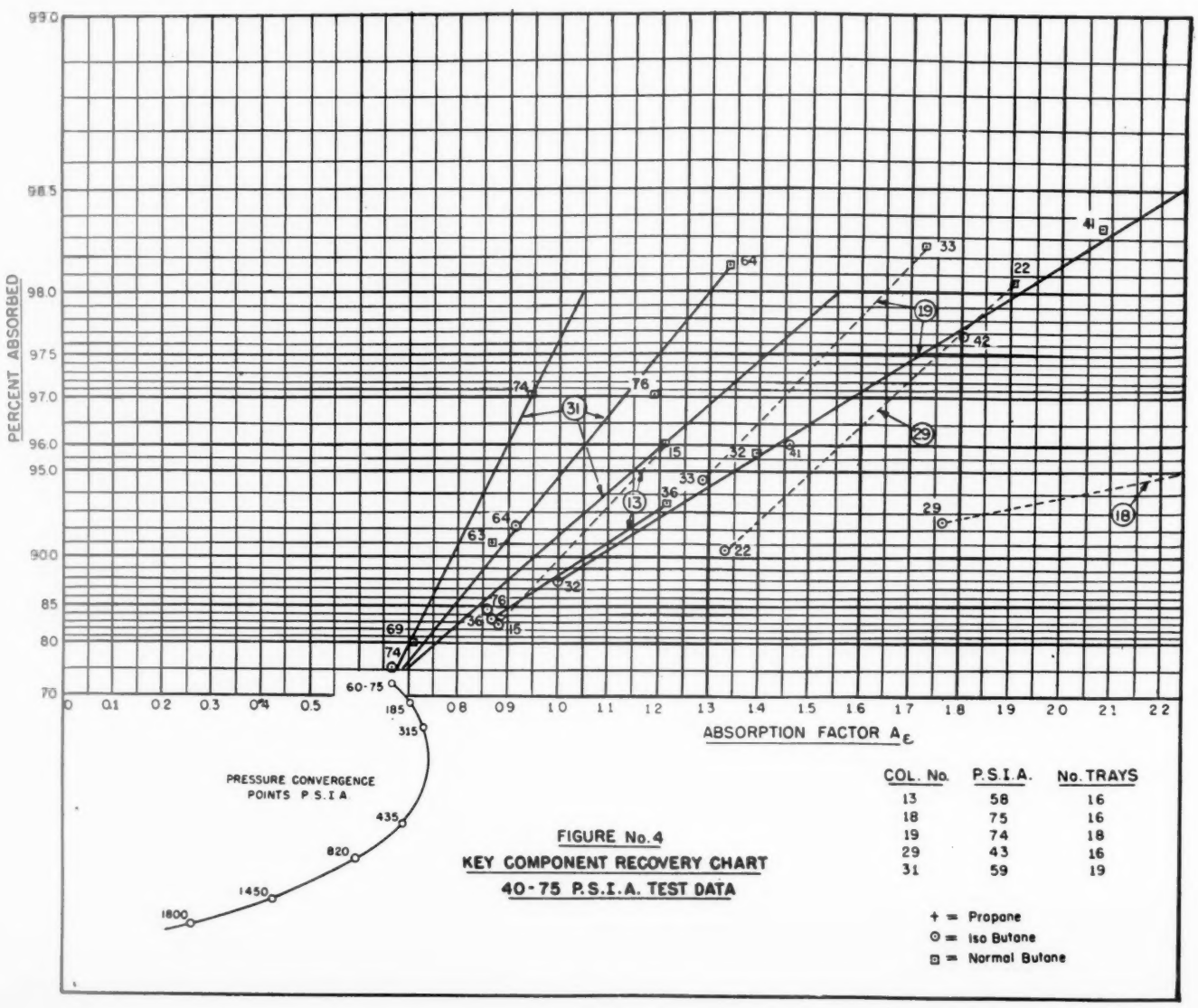
A_T = absorption factor at top tray conditions, and,

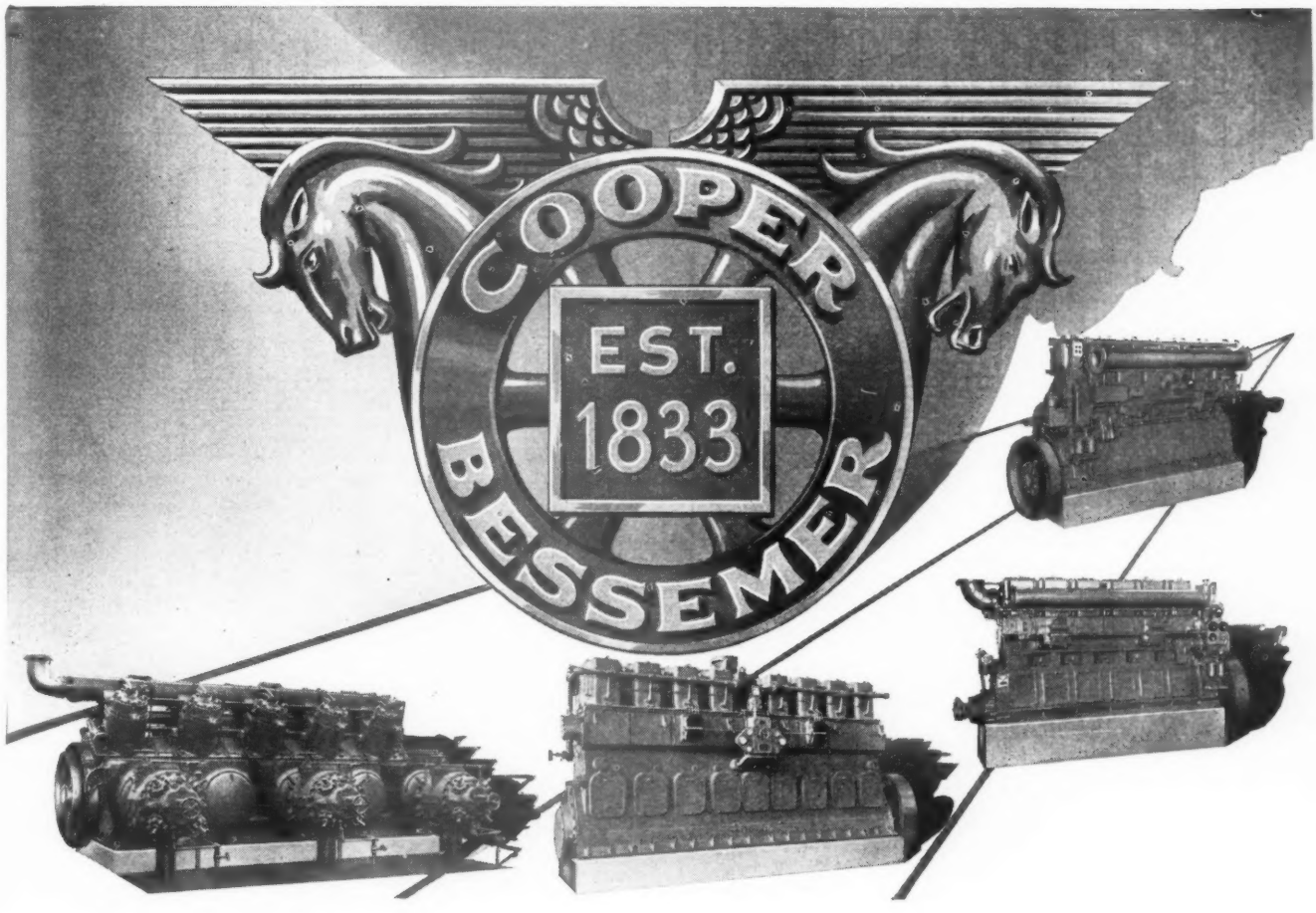
$A_n = \dfrac{L_n}{V_n} \cdot \dfrac{1}{K_n}$ = absorption factor at tray "n".

Although Edmister's original derivation assumed that K's based on the top tray temperature would be used for calculating the top plate absorption factor,

3. Edmister, W. C., *Ind. Eng. Chem.*, 35, 837 (1943).
4. Horton, George, and Franklin, W. B., *Ind. Eng. Chem.*, 32, 1384 (1940).

FIP. 4. 40-75 lb. per sq. in. abs. test data. Key component recovery chart.





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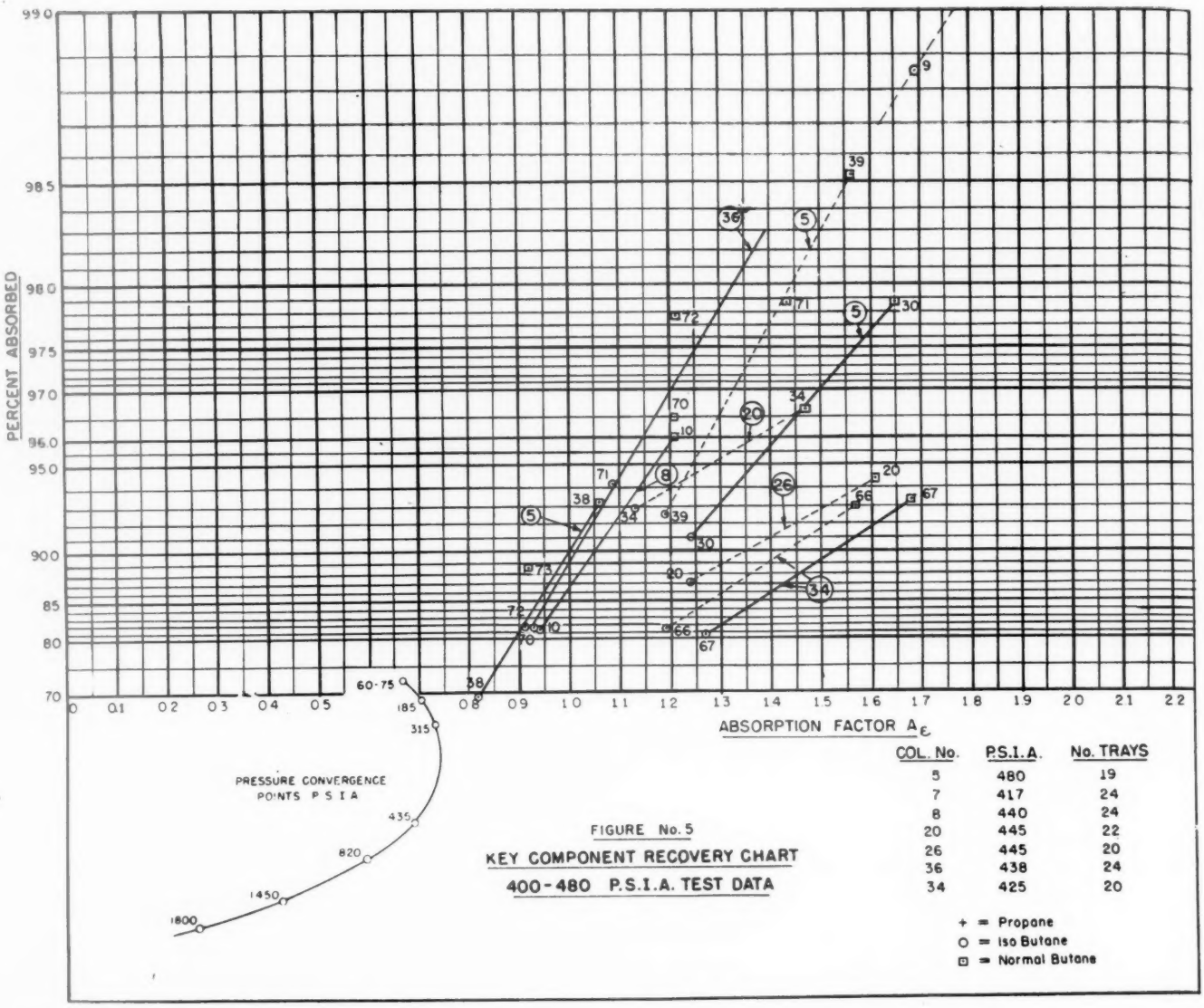

FIGURE No. 5

KEY COMPONENT RECOVERY CHART

400-480 P.S.I.A. TEST DATA

FIG. 5. 400-480 lb. per sq. in. abs. test data. Key component recovery chart.

we have used "K's" based on the temperature of the fat oil leaving the bottom of the column for calculating both the top and bottom "A" factors. Justification for this simplification lies both in the character of the temperature gradient existing through the average absorber, and the fact that it has proved thoroughly workable in practice.

Having decided on a method for determining A_e, component recoveries indicated by the test data were then calculated and plotted in the conventional manner on rectangular coordinate group-charts against appropriate A_e's—with each group chart being confined to a comparatively narrow operating pressure range. Figs. 2 and 3 are typical of these group plottings, and cover respectively 40-75 lb. per sq. in. abs. test data, and 410-480 lb. per sq. in. abs. test data. For comparison, we also plotted on these group charts the Brown curve for an eight-tray theoretical column.

Study of these group plots brought out the following pertinent points:

1. Although the operating lines for the actual columns were of the same general nature as the theoretical tray lines, they departed materially from the theoretical in detail.

2. Individual test lines indicated marked column differences both in general tray effectiveness and relative component recoveries — with these differences often being evidenced by a crisscrossing of lines, rather than by a systematic line displacement as on the theoretical Brown chart.

3. The rectangular plotted operating lines were difficult to interpolate accurately in the critical 75-95 per cent recovery range due to rapid curvature in this region.

4. Although it was clearly evident that some of the column tests were much less authoritative than others, no reliable criteria of general operation pattern, or individual test consistency, was presented by the rectangular plots.

These facts clearly called for a more effective graphical treatment of the data, and led directly to the development of the special "straight-line" Key Component Recovery Chart upon which our new analytical procedure is based.

With this new chart, all component recoveries between 75 and 99 per cent plot as a straight line for any given column as long as its basic tray efficiency remains constant. Furthermore, all such straight lines, irrespective of number of trays employed or degree of efficiency, can be drawn through a single convergence point for any given absolute pressure with an accuracy well within that required for precise engineering work. Finally, the characteristic operating lines remain fixed for any given column over wide ranges of lean oil temperatures, and for all types of intercooled columns as long as the intercooling is confined to the upper 75 per cent of the column.

These chart features stem from a special empirical scale construction — which scale, together with an associated group of pressure convergence points, was developed directly from actual operating data, and cannot be duplicated by any theoretical analysis of which we are cognizant.

The second and concluding part will be published in an early issue of *The Petroleum Engineer*.

Mr. Hoge goes to TEXAS

FRIDAY: Houdry Laboratories receive a long distance call from a Texas refinery, requesting assistance in the operation of a TCC unit. Wesley Hoge, able Houdry engineer, leaves by train the next day. (He would have flown but all planes were grounded.)

TUESDAY A. M.: Mr. Hoge arrives at the refinery, confers with Houdry's Texas representative and refinery management; then inspects unit.

THURSDAY NOON: At Hoge's suggestion, unit is shut down to permit examination of the reactor.

THURSDAY MIDNIGHT: Twelve hours after shut-down began, inspection of the reactor has been completed, mechanical adjustments made per Hoge's recommendations, and unit is ready to resume operation. Pretty good time, even for a TCC!

FRIDAY: Unit is operating at rated capacity and producing 1,000 B/D *more gasoline* than prior to shut-down. Mr. Hoge takes a bow but not his departure—he stays right there to make sure the operation stays right.

TWO WEEKS LATER: Even Mr. Hoge is satisfied and leaves for home. Refinery executives write nice letters to Houdry. It's really nothing extraordinary, just typical of the kind of service Houdry gives its licensees.

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Design, installation, and operation of gas lift equipment

By **LOUIS F. DAVIS,** *Senior Mechanical Engineer,* Atlantic Refining Company

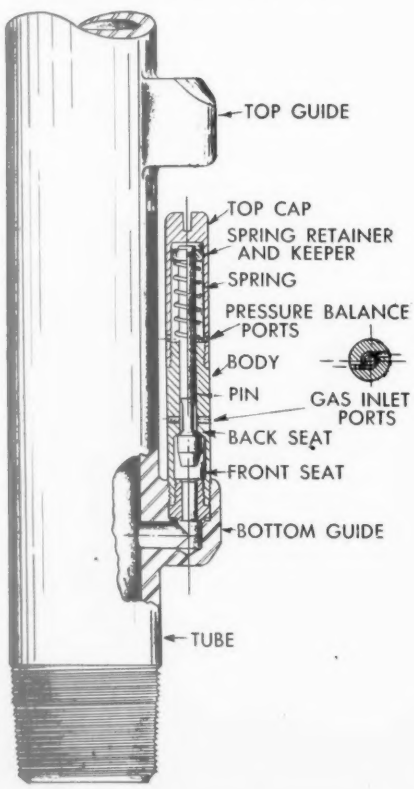
● **Abstract.** For every type of well there is a type of gas lift equipment most suitable. Automatic differential controlled flow valves are suitable for rates greater than 40 bbl. an hr., and lifts of less than 2500 ft. Surface controlled intermitters are suitable for any depth and rates from 1 bbl. a day up to 400 bbl. a day in 2-in. tubing, and 1000 bbl. a day in 2½-in. tubing. Other types of valves are available for varying well conditions. Sketches are included that illustrate the various types of valves.

For each type of equipment, formulae exist that facilitate the calculation of the proper setting depths for the various valves. Some variation is permissible from these formulae, based on local conditions.

For successful installation of gas lift equipment, there is required a clean well, field testing of equipment prior to installation, and the attention of an experienced man during the initial "kick-off" period.

EXCLUSIVE

FIG. 1. Automatic differential controlled flow valve.



For successful operation of gas lift equipment, constant and competent supervision is required to prevent gas wastage and high operating costs, especially where gas is purchased. Lift efficiencies vary widely, depending on the volumes handled, pressure available, feet of lift, type of equipment, etc. A table of lift data and efficiencies is given. Lowest efficiencies occur in West Texas stripper wells and highest efficiencies are in heavy volume water production with high fluid levels. Curves are given illustrating performance of gas lift equipment in various fields.

● **Introduction.** Gas lift equipment has had a stormy career in the oil industry. Many different inventors have patented ideas and special valves, of which a large number have been manufactured and tried—many of them with indifferent success. A few devices, however, have been very successful and their use has resulted in efficient and economical lifting of oil and water. In this article, an attempt will be made to explain the operation and proper application of these devices, and to outline a method of equipment selection. The economics of their installation is a broad subject and figures to substantiate any conclusions are not often published, because of a reluctance on the part of the oil operator to release information of this nature. Generally, it may be said that gas lift is probably the most economical method of artificial lift, provided an abundant supply of cheap gas is available. Where the gas must be obtained by purchase or by compression, then the operator is wise to judge each case on its own merits, after careful analysis of equipment, installation, and operating costs. Under these circumstances, it will be found that gas lift is competitive with other types of lift, and in the deeper horizons, is often the most economical form of lifting equipment.

● **Types of equipment.** In general, gas lift equipment may be divided into three main types: (1) The automatic differential controlled flow valve, (2) the specific gravity controlled flow valve, and (3) the surface controlled intermitters and flow valves.

A type of automatic differential controlled flow valve is illustrated in Fig. 1. The valve is given a differential by the action of the spring, which added to the weight of the column of liquid inside the tubing, opens the valve against the pressure of the gas in the annular space between the tubing and casing. This spring induced differential is ordinarily 100 lb. per sq. in. This figure was obtained by extensive experiments and field trials that proved its desirability over larger or smaller differentials. With smaller differentials, it is difficult to obtain the velocity of fluid travel needed for efficient operation, whereas larger differentials tend to cause excessive gas consumption, for the valves are difficult to close.

FIG. 2. Specific gravity controlled valve.

W—Well fluid in tubing.

L—Light oil which functions as a counter weight in the mechanism and which is placed in the 16 ft. "oil tube" of the valve prior to running in the hole.

Note: The light oil is open to the inside of the tubing at the top of the oil tube but is so arranged that no mixture takes place.

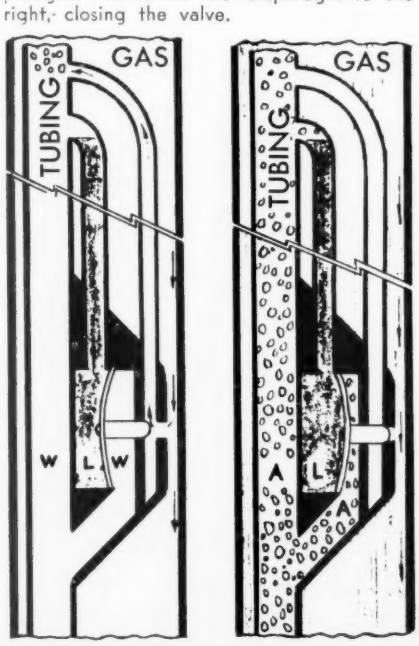
A—Aerated well fluid.

BECAUSE W IS GREATER THAN L:

Well fluid weighing against the right side of the diaphragm exerts a greater pressure than light oil and well fluid weighing against the left side of the diaphragm. This forces the diaphragm to the left—opening the valve.

BECAUSE A IS LESS THAN L:

Aerated well fluid weighing against the right side of the diaphragm exerts less pressure than light oil and aerated well fluid weighing against the left side of the diaphragm. This forces the diaphragm to the right, closing the valve.



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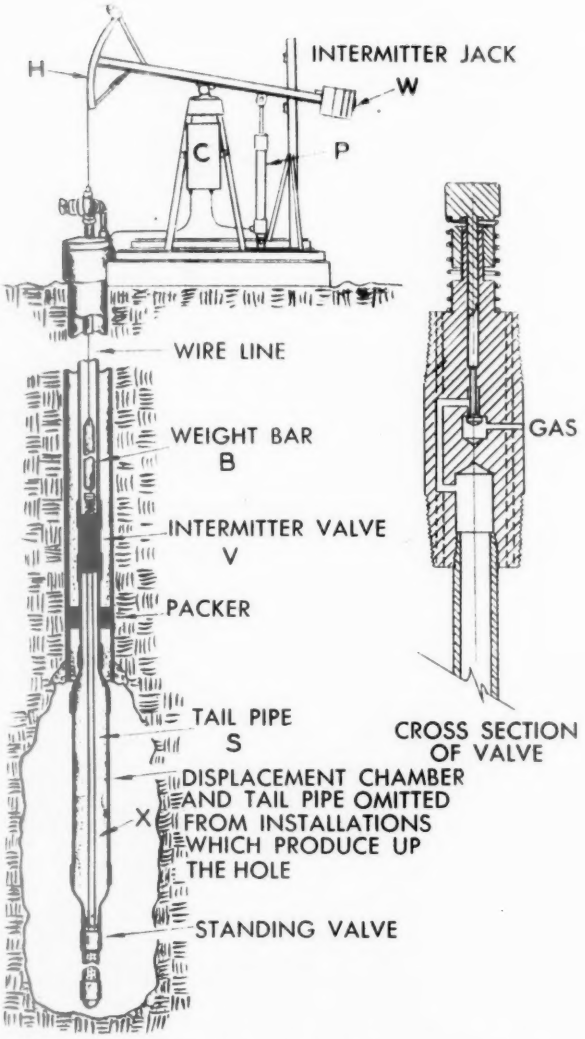

FIG. 3. Wire line controlled intermitter valve.

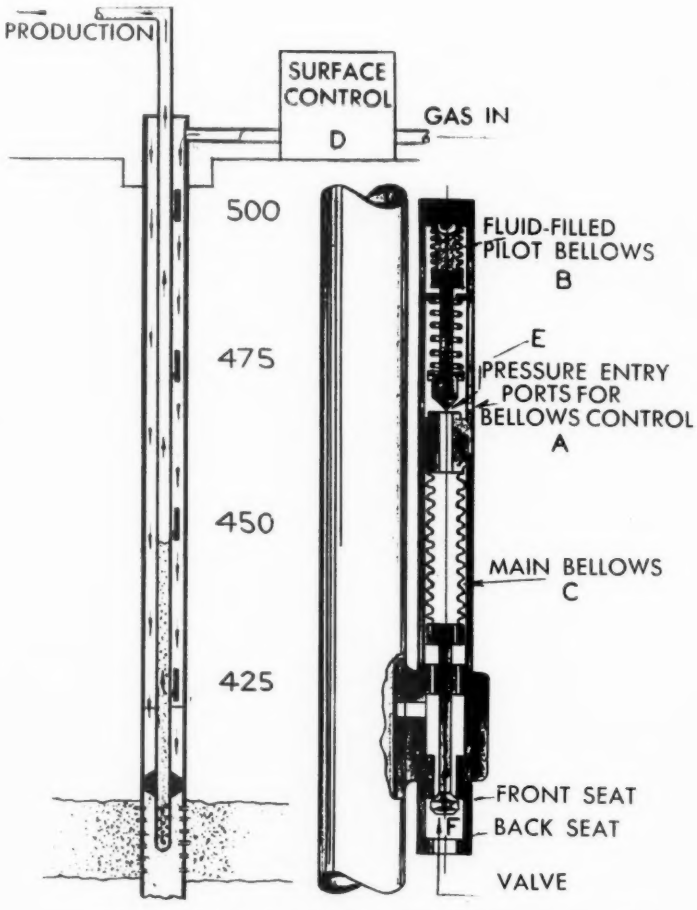

FIG. 4. Casing pressure controlled intermitter valve. (Figures are lb. per sq. in.)

Examination of Fig. 1 shows that normally the pressure in the casing holds the valve shut against the action of the spring, which rests on the front seat. As liquid builds up in the tubing above the valve, its pressure is added to the force of the spring until a sufficient amount has accumulated to open the valve against the casing pressure. Gas is then injected and the fluid in the tubing lifted to the surface. As the liquid is produced, the pressure in the tubing again declines and the valve shuts pending further accumulation in the tubing. In wells that have poor productivity, this results in a heading action; that is, a head of fluid is produced and then there is no further production until a fill-in has occurred to open the valve. Where the wells produce a considerable volume of fluid, the valve opens and shuts rapidly and the production is fairly steady. Here the action is one principally of aeration instead of intermission. Where the tubing pressure exceeds the casing pressure less the differential, the valve is shut against the back seat. This permits circulating the well with mud or water prior to pulling the tubing. The valves are set from 225 to 400 ft. apart, depending on the fluid to be lifted, differential, and position in the hole with relation to the working fluid level.

This type of valve has proved efficient and inexpensive to operate in wells that produce considerable quantities of fluid at relatively shallow depths. As a general rule, it might be said that the automatic differential controlled valve is most suitable for wells that have a producing capacity of 40 bbl. an hr. or greater, and where the operating fluid level is no more than 2500 ft. from the surface, although they will perform satisfactorily in smaller wells, if carefully installed and operated. Areas in which these valves have been quite satisfactory are the East Texas field, with the exception of some low fluid level wells on the east side; Conroe, Dickinson, the Hendricks field in West Texas, and many others of a similar nature.

The specific gravity controlled valve is illustrated in Fig. 2. By examination of this figure it becomes apparent that so long as liquid W of a specific gravity greater than that of liquid L, with which the valve tube is loaded, is opposite the valve in the tubing, the valve will remain open. Valves above that one producing and hence opposite a light fluid column such as A, will positively remain shut so long as an aerated column is moving past them. This is not always true of the automatic differential valve, which may pop open as the slug comes up the hole. A surface choke can be used with the specific gravity valve without changing valve opening characteristics. This is not always true in the case of the automatic differential valve, which can be held open by the improper use of chokes. These features make the specific gravity control more suitable for the deeper wells where a considerable number of valves are installed. The number of valves is also reduced due to the elimination of the differential. Valves can be set a considerable distance apart, depending on the casing pressure, fluid to be lifted, etc. This equipment has the limitation that there is no control over the amount of gas injected, other than the design of the port sizes, which of course must be done before installation, or by reduction of the input pressure, with a resultant loss in available energy. Therefore, more accurate information is desirable on producing capacities for string designs than with other types of equipment.

Three types of surface controlled valves are illustrated in Figs. 3, 4, and 5. Figs. 3 and 5 illustrate the wire line controlled intermitter, and in that illustrated in Fig. 4 the casing pressure is the controlling factor. Where the wire line type is used, some means must be available of unloading to the bottom intermitter valves. With the type of wire line

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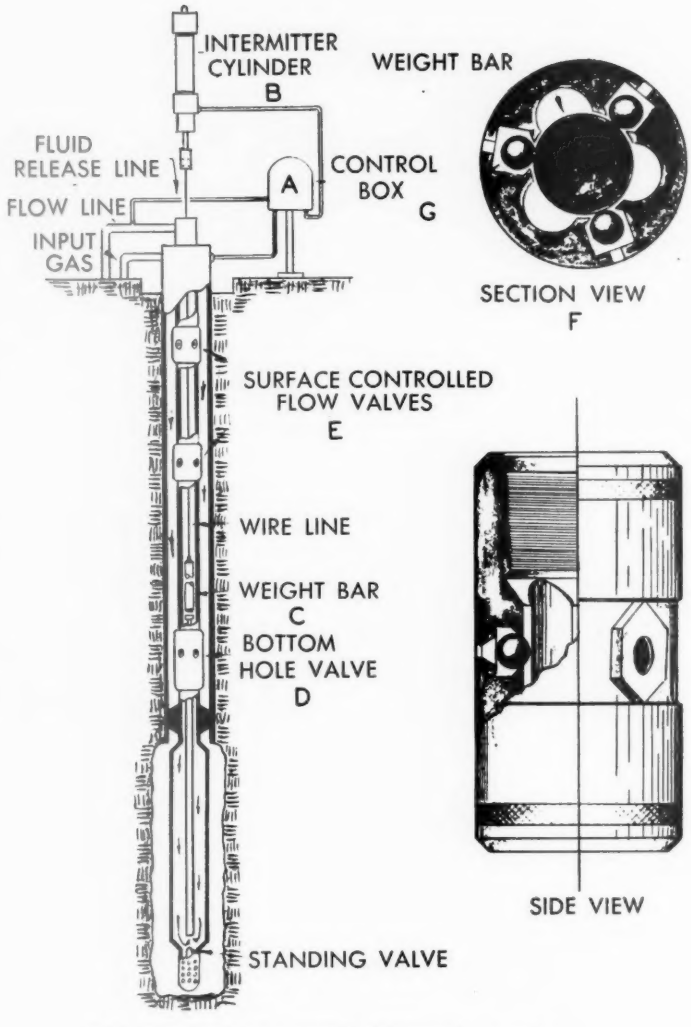

FIG. 5. Wire line controlled intermitter valve.

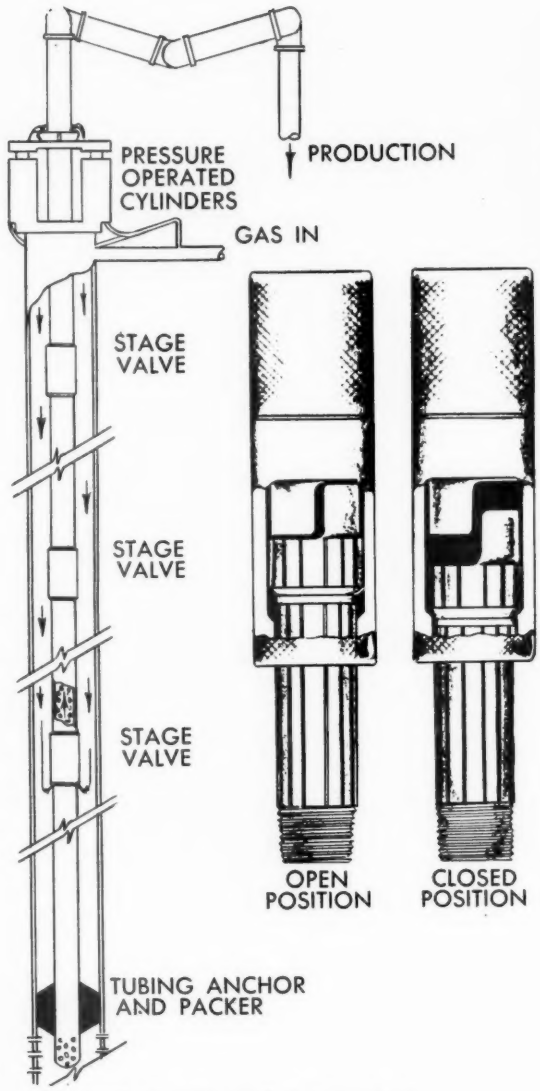

FIG. 6. Tubing controlled flow valve.

system illustrated in Fig. 5 this is done by successively moving the weight bar through the various valves in the string until the proper valve is reached. With the intermitter shown in Fig. 3, automatic differential valves are used where necessary as kick-off or unloading valves. With the casing pressure controlled intermitter, each valve is set to open at a slightly lower pressure than the valve above it, so that whenever the gas-liquid interface in the casing works down to a new valve, its opening reduces the casing pressure to such an extent that the valves above in the string are shut and remain so. The capacity of the valve in the well to pass gas is made greater than the gas injection rate at the surface, so that there will be no casing pressure build up beyond that necessary to open the operating valve, and the upper valves will remain closed.

The surface jack shown in Fig. 3 is equipped with a time cycle control "C." This can be set to admit gas at various intervals to cylinder "P." This lifts a piston that through a rod raises the weights "W" and pivots the jack so that the head "H" and wire line are lowered. This allows the sinker bar "B" to rest on the intermitter valve "V," open it and permit gas to flow from the tubing-casing annulus into the tubing tail pipe "S" and lift the fluid in the chamber "X." In cases where the working fluid level in a well is high, the intermitter can be set up the hole, and the tail pipe and accumulation chamber omitted.

Operation of the pressure controlled intermitter valve illustrated in Fig. 4 is as follows: Surface control D admits gas to tubing casing annulus. This pressure rise is passed through port A to outside of bellows B and lifts pilot valve E off seat, admitting gas to main bellows C, which opens valve F and allows gas to enter tubing. As illustrated in Fig. 4, valves are spaced in the hole with each valve down hole opening at a lesser pressure than the valve above it, so that valves above gas-oil contact in annulus are shut and remain so regardless of pressure or contents in tubing. The bottom valve can be equipped with tail pipe and accumulation chamber if desired.

Referring to Fig. 5, control box A admits gas to cylinder B, raising piston attached to wire line, which lifts weight bar off bottom valve D and thus allows gas to pass into tubing from tubing-casing annulus. Upper valves E are opened by raising bar into valve as shown in Section F and pushing balls G off their respective seats.

Intermitters are suitable for production rates of 1 bbl. a day up, their maximum capacity depending on the gas pressure available and the size of the tubing. Intermitting intervals of less than 5 min. are almost impossible of attainment. This permits 28 heads per day. The size of the head in barrels equals:

$$\frac{P}{G} \times C \times \frac{E}{100}$$

Where:

P = gas pressure at valve, lb. per sq. in.,

G = gravity of fluid lifted in lb. per sq. in. per ft. of height,

C = tubing capacity, bbl. per ft., and

E = lift efficiency.

Intermitter production rates attained from actual tests have run as high as 1000 bbl. per day in 2½-in. tubing, and 400 bbl. per day in 2-in. tubing

Surface controlled intermitters give low input ratios and effective performance in small wells. They are unlimited as to depth, successful installations having been made with lifts of more than 8000 ft.

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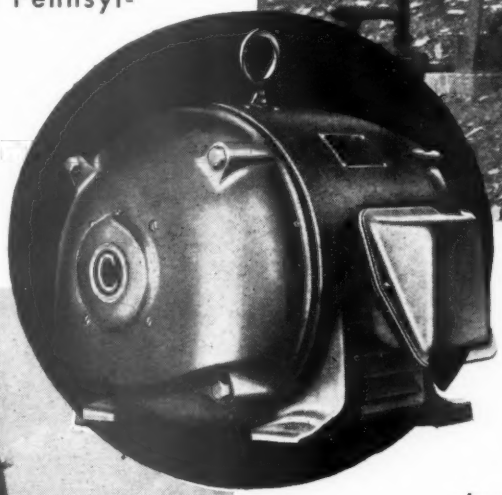

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There is another type of surface controlled flow valve that is suitable for specific applications. This is the valve illustrated in Fig. 6. This valve is operated by raising or lowering the string of small tubing on which it is installed. The tubing is anchored at the bottom and its manipulation is accomplished by the use of a screw lift or a hydraulic lift. With the tubing suspended from the surface, all valves are closed, and as the weight is transferred to the anchor by "slackening off," the valves open, the bottom valve opening first. By calibrating the surface lift, any desired valve, and those below it, can be opened. This equipment is particularly useful in cases where, because of casing leaks or stuck tubing, production is to be obtained without use of the annular space between the tubing and casing. They are also useful as kick-off valves to start production in normally flowing wells. They can be used as intermitters by injecting gas at intervals with a surface controller or installing automatic controls to raise and lower the tubing on a time cycle.

● **Installation design.** The first step in the selection of gas lift equipment is the determination of the conditions under which it will be operated. This involves a detailed study of the well in question. One must determine its productive capacity, both present and future, and both oil and water. The producing level must be obtained from tests, calculated from the productivity index or estimated. A forecast must be made of the allowable, and of the probable rate of future gross liquid production, and of the depths from which it must be lifted. These predictions and calculations are largely the work of the reservoir engineer, using his tools of material balance, relative permeability, subsurface pressure tests, production history, etc. The small operator who has no engineering department, can use the experience of offset operators, or make assumptions and trial installations, changing these as more information is obtained. Or, he can retain the services of a consultant skilled in this type of work. A study must also be made of the gas supply in the area to determine whether it will be available consistently over a period of years. When all this information has been obtained as accurately as possible, then there can

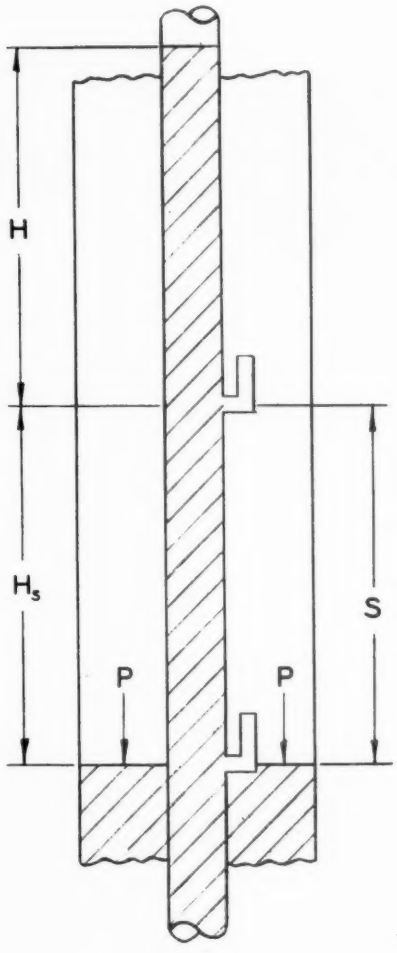


FIG. 7

begin the design and selection of the equipment.

Next comes the selection of the operating gas pressure. This, in some cases, will not be the pressure presently available, for whatever pressure is selected must be on hand for the number of years it is expected to operate the equipment, or the equipment reset as the pressure changes. If the supply of gas comes from a gas reservoir under pressure, sufficient allowance must be made for pressure decline so that the design pressure will be available until the oil wells are depleted. If the gas is supplied by compressors, the pressure selected will depend upon the depth of the wells and the economics of compression. Generally speaking, the higher the pressures that can be used, the greater the efficiency that will be obtained. This increase in efficiency is due to the reduction in slippage, which is proportoinal to the velocity obtained, which in turn depends on the pressure available for lift. A handy rule of thumb is to use a minimum 100-lb. pressure for every 1000 ft. of depth and a minimum pressure of 250 lb. per sq. in. regardless of depth. Under this rule, wells 2000 ft. in depth would be lifted by 250-lb. pressure and those 8000 ft. by 800-lb. pressure. Each case, however, must be carefully checked so that efficient lift is not obtained at the cost of exorbitant compression charges.

With the well characteristics known, and the operating pressure selected, the type of valve most suitable must be chosen. For best results the services of an engineer experienced in gas lift installations should be utilized. He can examine the facts, analyze the problem, and recommend the equipment most suitable for the particular operator. Here economics play an important part. The cost of the other types of artificial lifting equipment that could be used must be compared to gas lift costs. Operating costs, interest rates, payout, etc., must all be considered in the overall economic picture; however, this is another problem, and as this article is limited to consideration of gas lift equipment only, it is assumed that the decision is for gas lift and the proper type of valve has been selected.

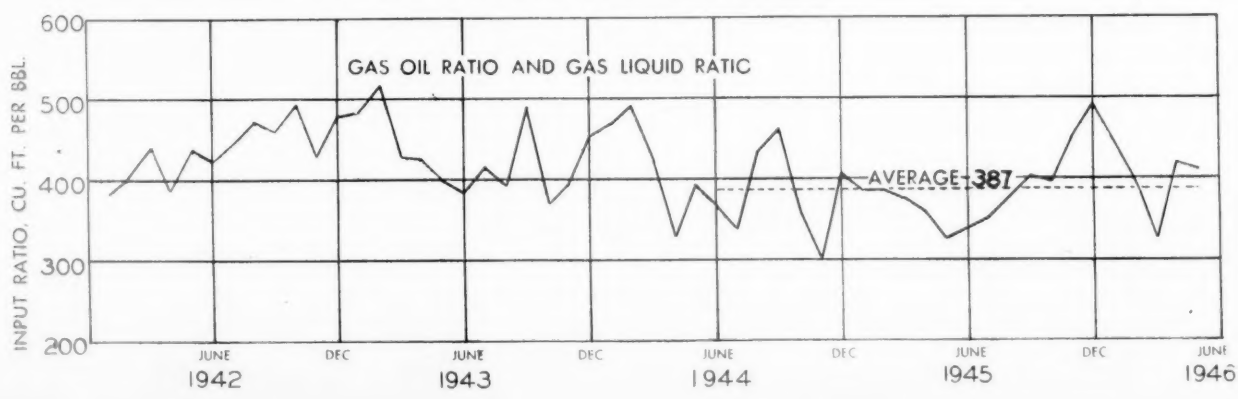
Next, the depth of the producing valve must be determined. This depth equals the producing level at the rate desired, plus the valve submergence. The submergence can be obtained by dividing the available gas pressure minus 100 lb. per sq. in. by the weight of the fluid to be lifted in lb. per sq. in. per ft. of height. The spacing of the upper or unloading valves is then determined in the following manner.

Spacing of the first valve:

1. Where static liquid level is near the surface:

$$S = \frac{P - D}{G}$$

CURVE 1. Gas lift operations East Texas field.



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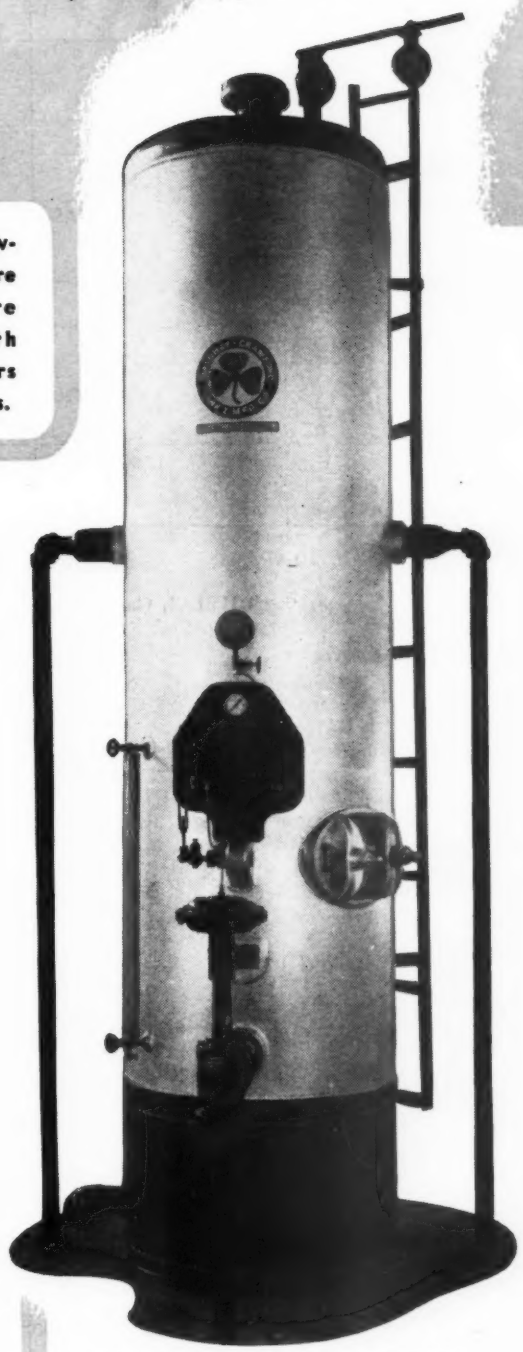

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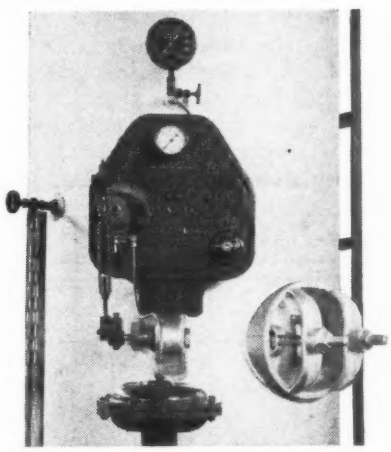

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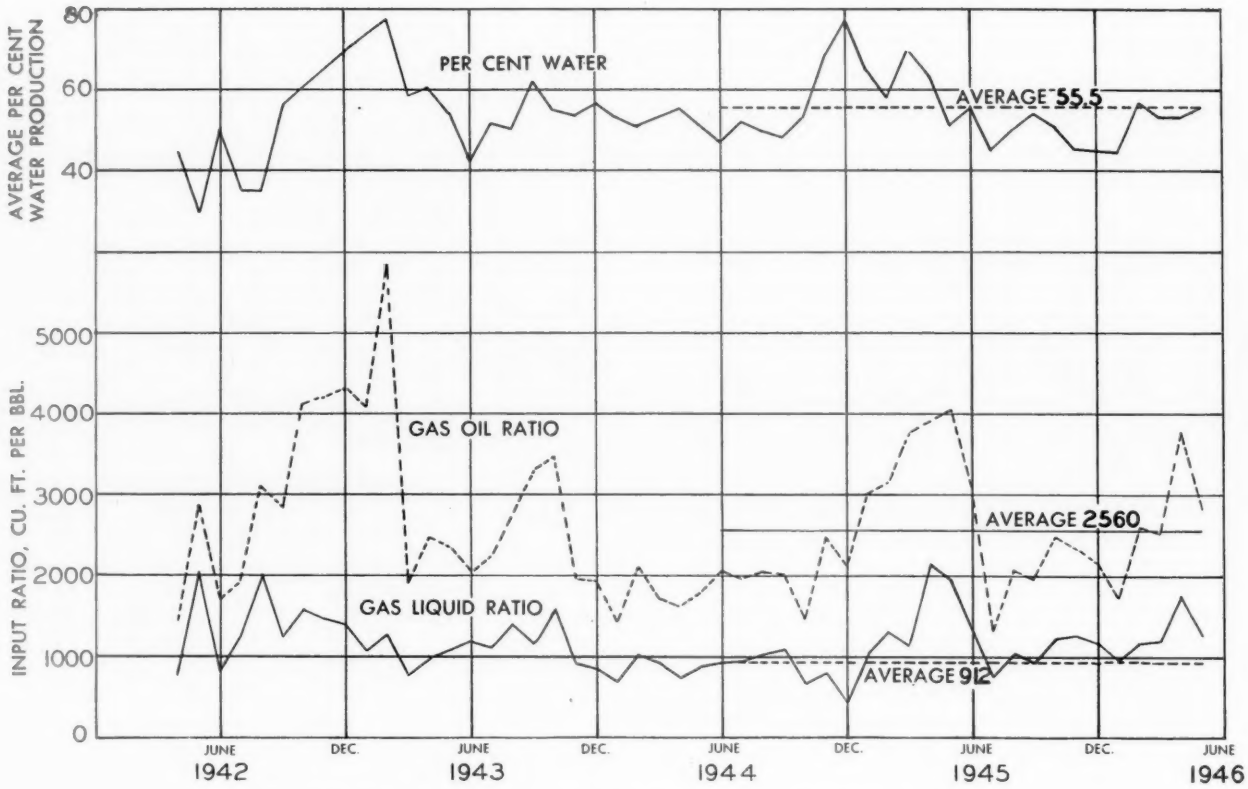


CURVE 2. Gas lift operations Neale field, Beauregard Parish, Louisiana.

Where:
S = spacing in ft.,
P = available pressure, lb. per sq. in.,
D = differential desired, usually 100 lb. per sq. in., and
G = gravity of fluid is lb. per sq. in. per ft. of height.

2. Where static liquid level is below the surface, a distance in excess of S as calculated in (1):

$$S = S.L. + \frac{1}{G}\ \frac{P - 100}{R + 1}$$

Where:
S. L. = static liquid level, and
R = ratio of annulus volume over tubing volume.

Spacing between valves:

1. Differential control valves:

$$S = \frac{D}{G}$$

Where:
D = valve differential in lb. per sq. in.

This formula may be derived as follows:

Referring to Fig. 7:
S = spacing between valves, ft.,
D = valve differential, lb. per sq. in.,
P = gas pressure, lb. per sq. in.,
H = static head required to open valve, lb. per sq. in.,
H_s = fluid head between valves, lb. per sq. in.
G = gravity of fluid in lb. per sq. in. per ft. of height,
H = P—D, and
H_s = SG.
P must balance $H + H_s$, so:
$P = H + H_s$ substituting
$P = (P - D) + SG$

Solving for S:

$$S = \frac{P - (P - D)}{G} = \frac{D}{G}$$

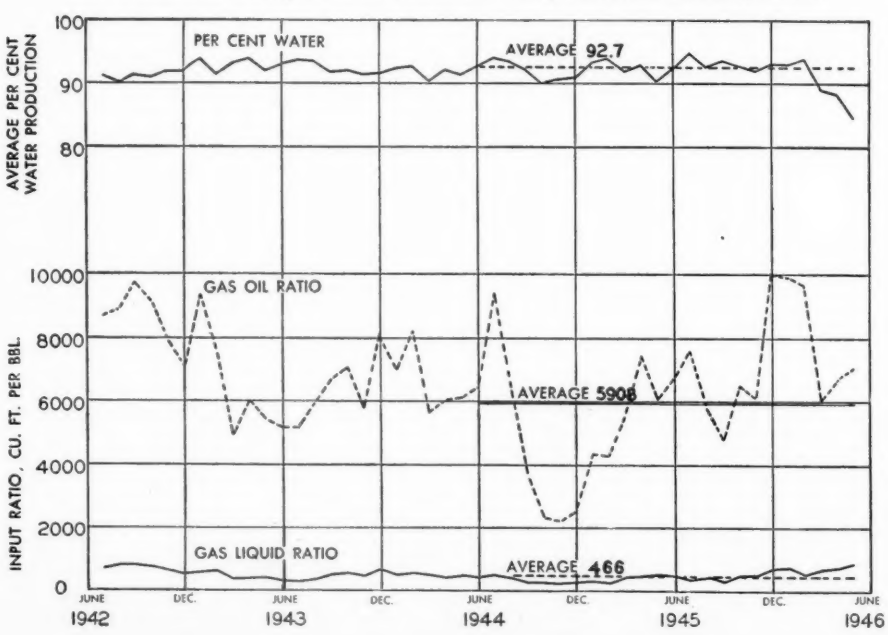
2. Surface controlled or specific gravity controlled valves:

$$S = \frac{P \times 0.7}{G}$$

Certain departures from the formulae given are possible.

The top valves in a string of automatic differential controlled valves can be spaced wider by 50 per cent more than the formula indicates, provided one is certain the working liquid level is down the hole. The bottom valves in a string

CURVE 3. Gas lift operations Dickinson field, Galveston County, Texas.



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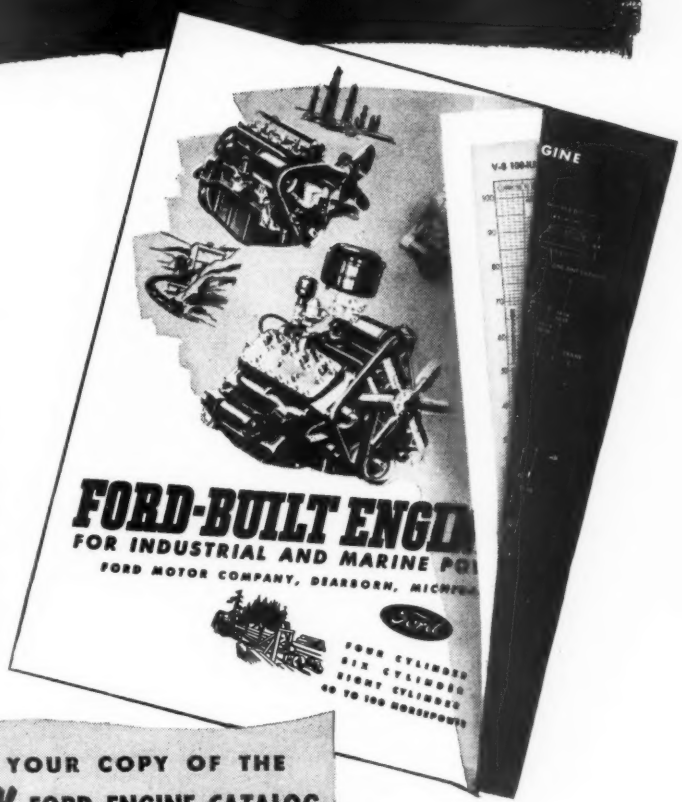

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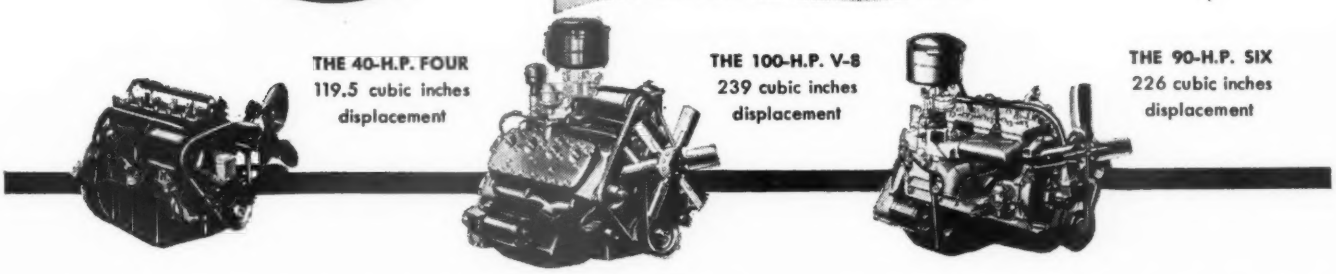

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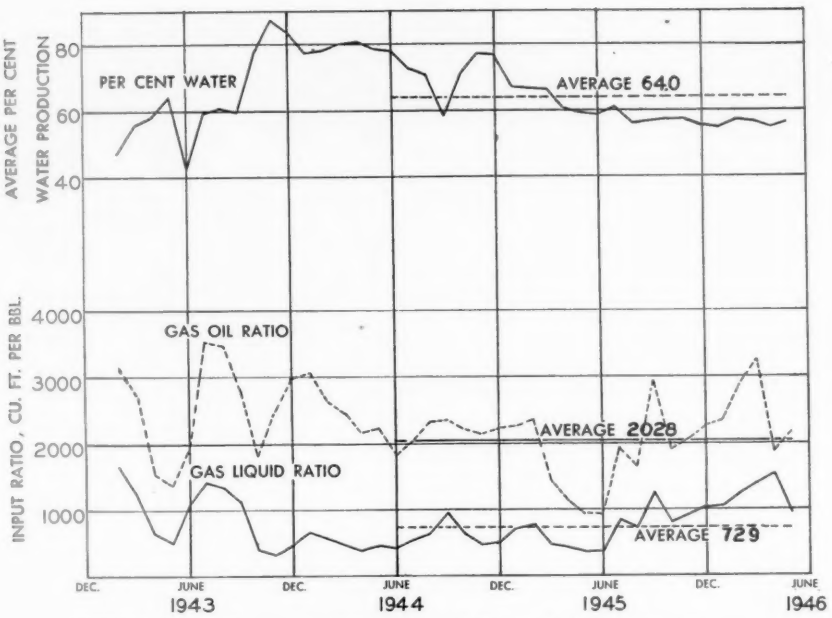


CURVE 4. Gas lift operations Greta field, Refugio County, Texas.

of surface of specific gravity controlled valves should be set closer than indicated, if there is any doubt about the well working down to the bottom valve. Otherwise the operating valve may not produce enough and yet the next be difficult to operate due to the high productive capacity of the well at that point. Aside from these cases, the formulae given should be closely followed if efficient operation is to be attained.

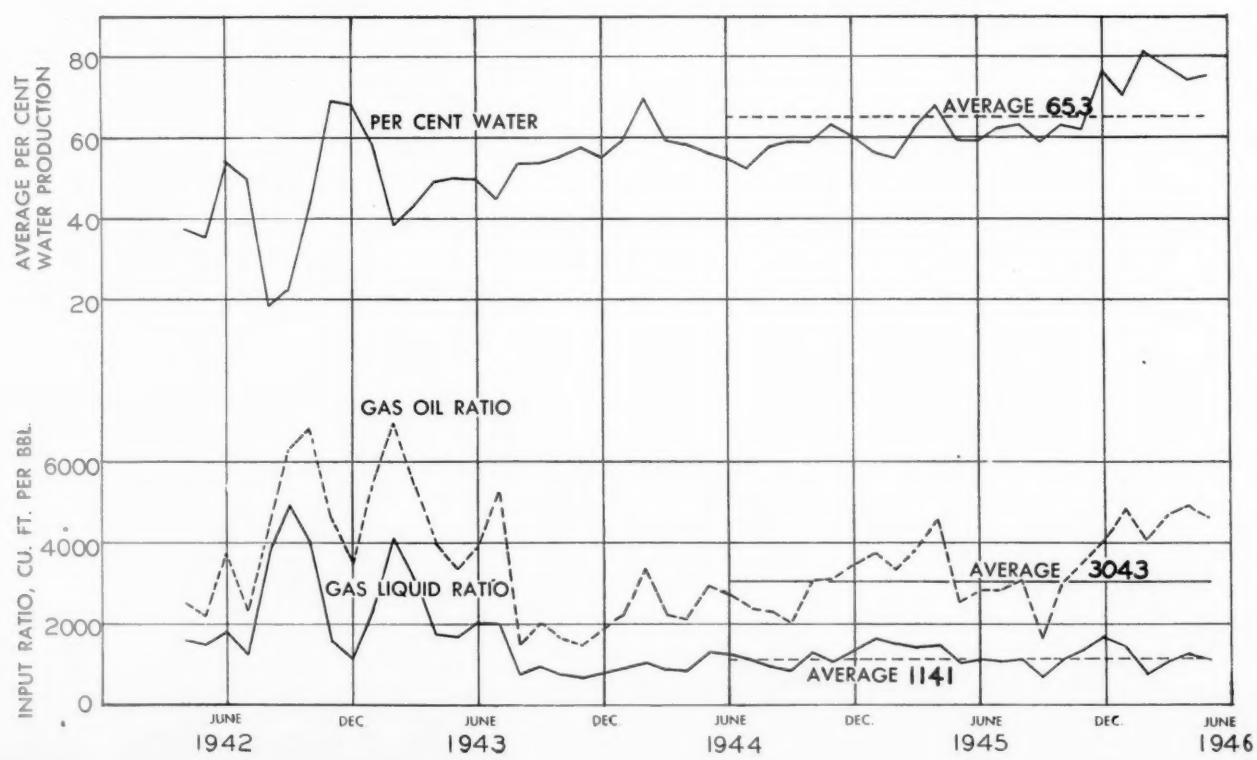
In all cases, the pressures used in design should not exceed the normal line pressures, if trouble free operation is to be obtained. Any setting that requires special high "kick-off" pressures to start operations will prove troublesome, and this factor may lead to the failure of some installations, because of the reluctance on the part of the field personnel to make the pressure changes necessary for proper operation.

● **Installation.** The proper installation of gas lift equipment in the field is fully as important as the selection of the equipment, and certain precautions must be followed. The equipment must be checked and tested to be sure that the specifications have been followed by the manufacturer. The wells must be clean and free from debris such as soft rope, packer rubbers, etc., for this material will clog the ports in the valves, and in many cases make necessary a pulling job before successful operation can be obtained. When the equipment is initially placed in service, someone quite familiar with its operating characteristics should be present. As wells are often loaded with water and the valve ports may be designed for a mixture of oil, water, and gas, considerable difficulty may be experienced in the preliminary operation of the equipment. If an experienced man is not present, the report may be received that the equipment is faulty and the well can not be kicked off, when all that is needed is a little patience and manipulation of casing and tubing pressures.

Of particular importance is the testing in the field of valves. Most flow valve manufacturers have set up rigid testing and inspection procedures; however, occasional slip-ups do occur and one faulty valve can ruin an entire installation. Many so-called valve "failures" occur in the manufacturer's shop, and are not apparent in the field until after several months of service due to the location of the valve below the liquid level in the well. All valves should be tested with gas pressure in the field before installation. Test blocks can be made easily and cheaply from standard fittings, and the time and effort thus spent are small compared to that involved in pulling tubing to repair a failure after installation.

● **Operation.** Constant and competent field supervision is vital for the successful operation of gas lift equipment. This is especially true where gas is purchased.

CURVE 5. Gas lift operations Seven Sisters field, Duval County, Texas.



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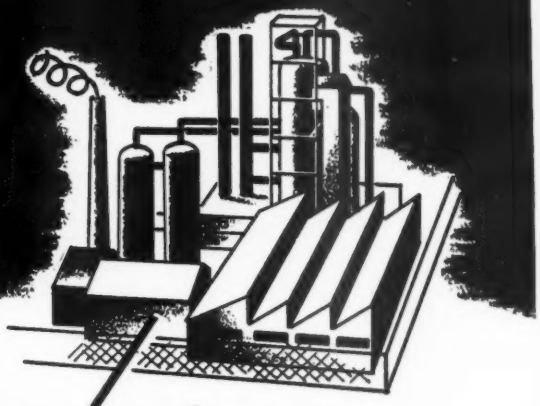

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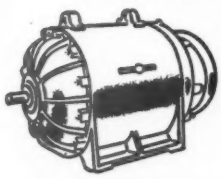

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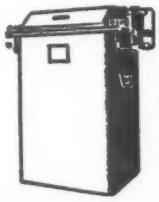

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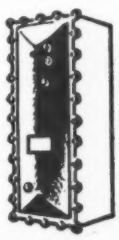

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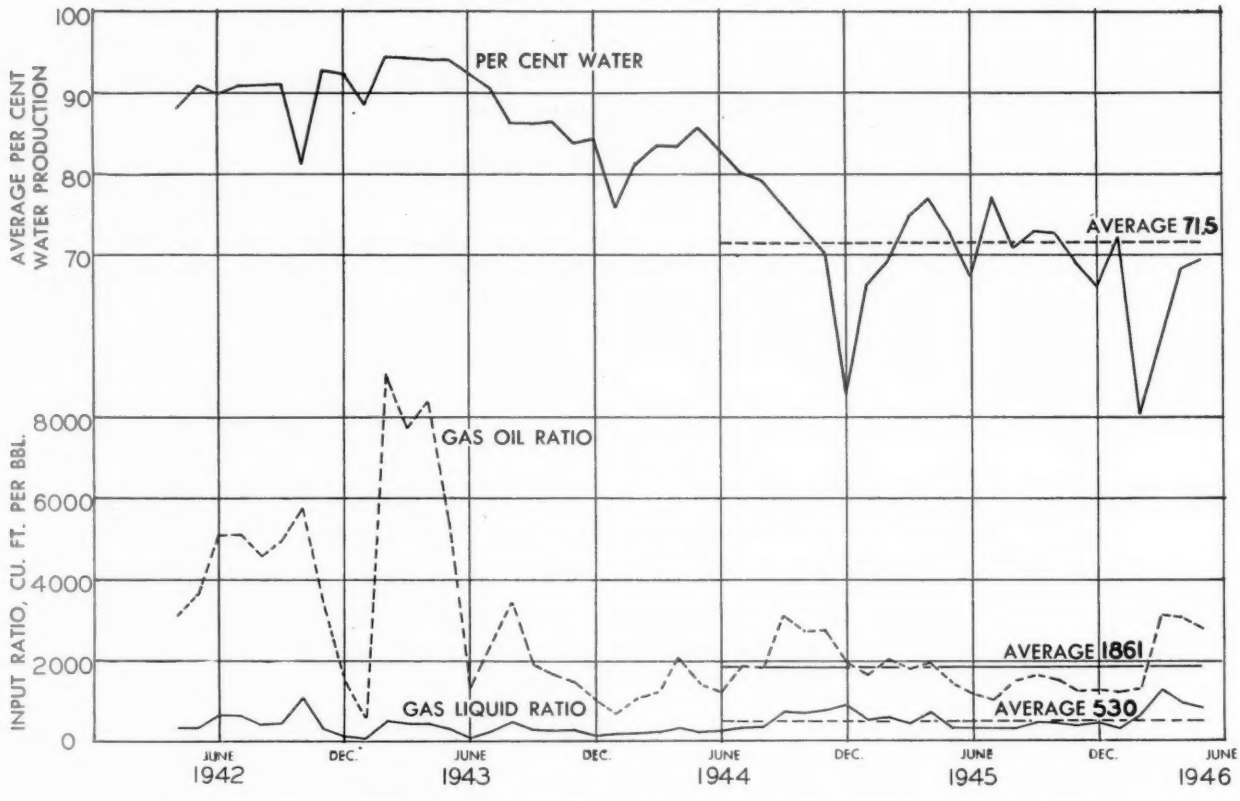
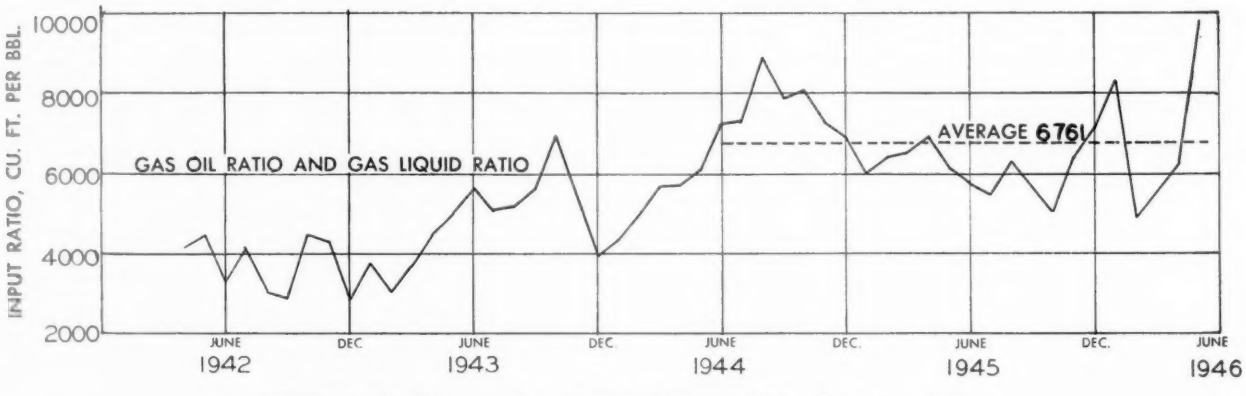


CURVE 6. Gas lift operations Aransas Pass field, Aransas and San Patricio Counties, Texas.



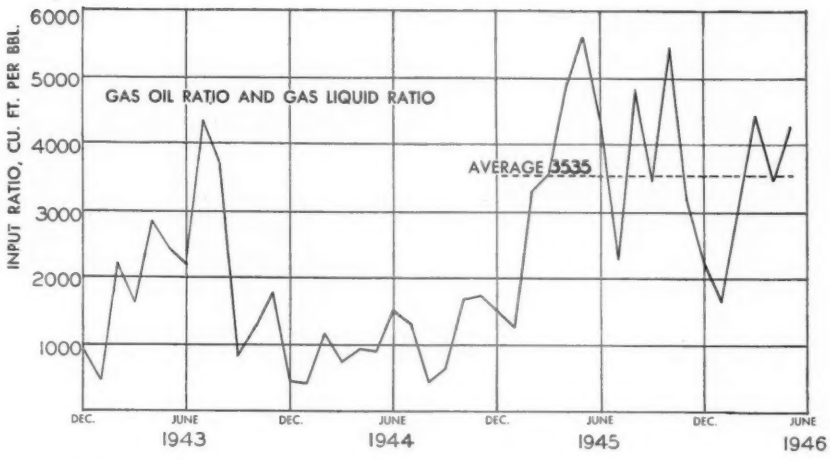
CURVE 7. Gas lift operations South Ward field, Ward County, Texas.

A careless or ignorant pumper can waste hundreds of dollars per month when gas is being bought at 4 to 5 cents per 1000 cu. ft. Frequent testing of wells and education of the field personnel is necessary in order to obtain satisfactory input ratios. All meters measuring gas should be checked monthly by a competent meter repairman. If possible, input ratios should be taken monthly, though if the gas consumption is satisfactory and the allowable is being produced without trouble, quarterly tests are often sufficient. The equipment must be repaired promptly when the need arises, as continued operation of faulty valves results in excessive gas consumption and high lifting cost. Flow tests with a subsurface pressure gage have proved very valuable in detecting the causes of faulty performance, and thereby insuring the success of later repairs.

Curves 1 to 8, inclusive, provide data on the operation of gas lift equipment in several areas by a major operator. Table 1 gives lifts, efficiencies, etc. The period covered by these computations is from June, 1944, to May, 1946, inclusive. These are discussed in detail, as follows:

Curve 1 shows data on gas lift operations in the East Texas Field. The wells are in the southeast portion of the field and are producing by means of flow valves and wire line intermitters. Gas is supplied at approximately 270-lb. pressure and the average lift is about 2500 ft. Very little water is lifted, most of the production being on the east side of the field where the wells are water free. Input ratios vary between 300 and 500 cu. ft. per bbl. and have been in this range over a period of some ten years. Average input ratio for the last two years has been 387 cu. ft. per bbl. This gives a lift efficiency of 29.9 per cent, assuming a lift of 2500 ft. and isothermal gas expansion. Some installations have operated without repairs for more than ten years. Gas is obtained from a gasoline plant that processes the lease casinghead gas and returns it under pressure.

Curve 2 represents gas lift operations in the Neale field, Beauregard Parish, Louisiana. The wells in this field are largely equipped with the bellows type casing pressure controlled intermitters. Protuctivity indices are poor and the average lift is estimated at 5000 ft. Efficiency is 22.7 per cent. Gas-oil ratios fluctuate violently due to the varying percentages of water produced, but injected gas-liquid ratios are fairly constant and good performance is obtained, as can be seen from the efficiency quoted. For the last two years, input gas-oil ratio has been



CURVE 8. Gas lift operations Goldsmith field, Ector County, Texas.

TABLE 1

Field	Injected		Per cent water	API gravity oil	Specific gravity of liquid lifted	Feet of lift	Ft.-lb. required to lift 1 bbl. at 100 per cent eff., thousands	Injected gas pressure	Actual ft.-lb. per bbl. used, thousands	Eff. of lift, per cent
	Gas-oil ratio	Gas-liquid ratio								
East Texas	387	387	negligible	39	0.830	2500	726	270	2,428	29.9
Neale	2560	912	55.5	37	0.935	5000	1636	600	7,207	22.7
Dickinson	5908	466	92.7	37	1.025	2500	897	600	3,682	24.3
Greta	2028	729	64.0	23	0.994	2000	696	800	6,196	11.2
Seven Sisters	3043	1141	65.3	23	0.994	2000	696	300	7,400	9.4
Aransas	1861	530	71.5	43	0.972	3500	1191	650	4,276	25.5
South Ward	6761	6761	negligible	32	0.865	2300	696	380	48,848	1.4
Goldsmith	3535	3535	negligible	36	0.845	3500	1035	480	27,230	3.8

Figures in this table are for the period from June, 1944, to May, 1946, inclusive, except for Goldsmith, which is from June, 1945, to May, 1946, inclusive.

2560:1 gas-liquid ratio 912:1, and per cent of water 55.5.

Curve 3 represents gas lift operations in the Dickinson field, Texas Gulf Coast. Here the average lift is 2500 ft., efficiency 24.37 per cent. Large quantities of water are produced, the average water production being 92.7 per cent for the last two years. Gas-oil ratios fluctuate widely, as would be expected, but the gas-liquid ratio remains fairly constant at approximately 465 cu. ft. per bbl. The wells are equipped with automatic differential type flow valves, casing pressure controlled intermitters, and wire line intermitters. All three type have proved satisfactory. The automatic flow valves were used in large high level producers, the wire line intermitters in the medium level large volume producers, and the casing pressure controlled intermitters in the low level producers. Gas is supplied from gas wells.

Curve 4 represents gas lift operations in the Greta field, Refugio County, Texas. Lift is 2000 ft., efficiency 11.27 per cent. Per cent water production is 64. The injected ratios are 2028 and 729 cu. ft. per bbl. Most of the production is obtained by means of automatic differential controlled valves, which have been installed for approximately ten years. The amounts of gas injected are largely controlled by chokes on the surface, and operations are only efficient when large volumes are produced. The present installations are gradually being replaced with casing pressure controlled valves as individual tests indicate the need for this equipment. Gas is from gas wells.

Curve 5 represents gas lift operations in the Seven Sisters field, Duval County, Texas. Here the lift is 2000 ft., water percentage 65.3, lift efficiency 9.4 per cent. Injected gas-oil was 3043:1, gas-liquid ratio 1141:1. Automatic differential controlled valves and wire line intermitters are used. Gas is supplied by a compressor station, which cycles the gas. The low efficiencies are due to the stripper nature of a portion of the production.

Curve 6 represents gas lift operations in the Aransas field, Aransas and San Patricio counties, Texas. Water production is 71.5 per cent, lift 3500 ft., efficiency 25.5 per cent. Injected gas-oil ratio is 1861:1, gas-liquid ratio 530:1. Gas is from a compressor station, which cycles the gas. The wells are produced by casing pressure controlled intermitters and automatic differential control valves. The latter are being replaced as rapidly as possible, due to their high susceptibility to sand cutting, which has given trouble in the past in this area.

Curve 7 represents production in the South Ward field, Ward County, Texas. Lift is 2300 ft., water production is negligible, efficiency is 1.44 per cent, injected gas-oil ratio 6761:1. This is stripper production, the wells producing from 3 to 10 bbl. a day. They are all equipped with wire line intermitters and produce from the bottom of the hole. Gas-oil ratios are high, for the light loads make considerable after-blow mandatory in order to obtain the production. Gas is from a gasoline plant in the vicinity, which returns compressed residue. Close supervision of this type of property is required, for, due to the small volume of oil produced, slight volumetric changes in the gas consumption have an appreciable affect on input ratios.

Curve 8 shows gas lift operations in the Goldsmith field, Ector County, Texas, from June, 1945, to May, 1946, inclusive. Here the lift is 3500 ft., water production is negligible, efficiency 3.8 per cent, injected ratio 3535:1. The wells are equipped with casing pressure controlled intermitters. The increase in input ratios during 1945 represents a change from agitation to true lift caused by a bottom-hole pressure decline. Considerable trouble due to corrosion of both surface and subsurface equipment accounts for the violent fluctuations in input ratios. Gas is from a gas well.

Table I lists all the operations just described and shown in Curves 1 to 8. The lifts given in this table were determined by using available pressure data and field experience and tests.

If it is desired to estimate probable ratios in a new area, they can be approximated by selecting a field given in Table I, where the conditions most closely fit the case in question, and adjusting the values given to local conditions. It is safe to assume that in areas where there is an appreciable amount of liquid to be lifted, efficiencies can be obtained of from 20 to 30 per cent. If the product is of the stripper type, efficiencies will be low, from 1 to 5 per cent.

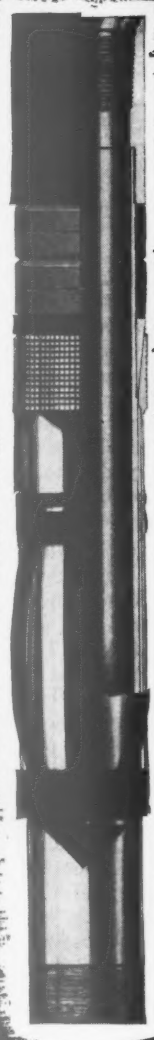
★ ★ ★

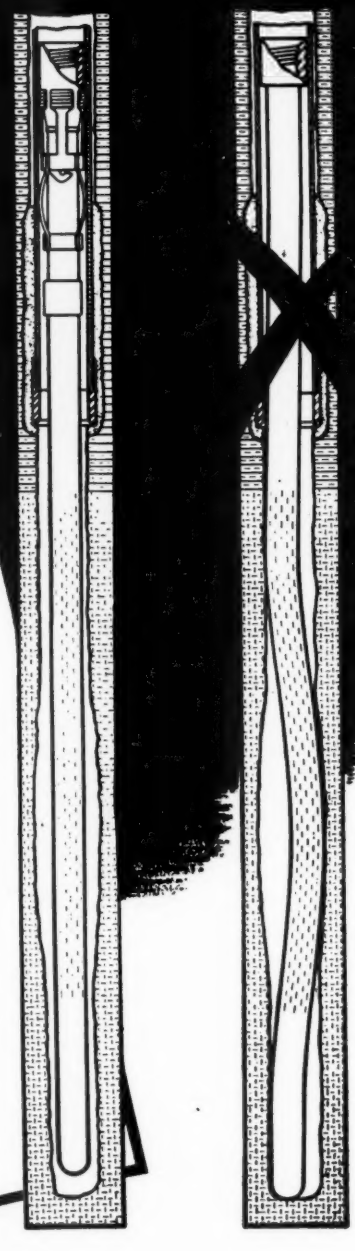
U. S. oil and gas map

Oil and gas fields of the United States, major refining centers, and all major oil, gas and petroleum products pipe lines, are shown on a new map released by the U. S. geological survey, Director William E. Wrather has announced.

The map is printed on two sheets, each measuring 41 by 51 in. Copies may be obtained from the Director of the Geological Survey, Washington 25, D. C., at $1.50 for the set of two sheets.

The new map, which is on a scale of approximately 1 in. to 40 miles, shows fields developed to March 1, 1946. The Big Inch, the Little Inch, the Tennessee Gas and Transmission Company's 24-in. line, the Plantation gasoline line and other lines built during the war are included in the network of pipe lines shown on the map.





Lane-Wells Liner Hangers provide the support necessary to allow liners to hang straight without buckling or deforming the screen. As a result rods, tubing and pump are permitted to work without interference. Wear is reduced and operational life increased.

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Present trends in alloys*

IMPORTANT progress has been made in the field of metallurgy during the war years that is being used to advantage in the present postwar period. Many new alloys have assumed their place in the metal industry, and as raw materials become more readily available it is expected that wider use of alloys throughout industry will result.

● **Alloy steels.** A broad series of standard triple alloy steels containing nickel, chromium, and molybdenum, in which all the significant alloying elements are under precise control, have become available to industry as a result of wartime experience. These steels accounted for an exceptionally large tonnage during the war and are still being employed in large quantities by users who find the controlled chemistries of such steels useful in assisting the maintenance of uniformity of their products. Of particular significance is the triple alloy steel tubing of the 8630 type, which finds use in the aircraft industry because of its strength, ease of forming, and ready weldability. Another outstanding development has been the application of 8650 steel for heavy duty springs. Hardenability, toughness, and improved surface qualities of this steel have led to its growing favor.

There also has been considerable return to popularity of the standard prewar alloy steels. Of the carburizing types, the 4600 series appears to be growing in demand, not only because of the properties developed, but because distortion as a result of heat treatment is minimized. For heavy duty carburized parts the 4300 and 3300 steels are generally employed. In the direct hardening grades, the 3100, 4600, 8600, and 2300 steels enjoy popularity, with the nickel-chromium-molybdenum 4340 steel being widely used for highly stressed parts of heavy cross-section.

The low alloy high strength rolled steels are receiving increased attention from designers because of the savings in weight that can be achieved by utilizing their improved strength. These steels also possess unusually good response to cold forming and welding operations. The railroad industry in particular is tending to favor these steels for freight cars, reducing deadweight and increasing payload capacity.

● **Stainless steels.** The demands for stainless steels continue to increase. It is estimated in trade circles that 1946 production will exceed or at least equal that of 1945. Of all stainless steel produced, the chromium-nickel types comprise more than two-thirds of the total.

Particular popularity is enjoyed by the two grades, AISI 302 and 304, containing about 8 per cent nickel. Both types are well suited to assembly by welding, but type 304 because of its low carbon content is better suited for welding without subsequent heat treatment. Increased interest is also exhibited in stainless steel containing molybdenum (type 316), because of its ability to withstand certain specific corrosion conditions. This particular alloy finds increased use in chemical, paper, and related industries.

Although the demands for stainless by the aircraft industry have been drastically curtailed over the war period, it is predicted that this industry will continue to depend upon stainless steels in the airplanes of the future. The utilization of stainless steels, because of their strength and formability in addition to their resistance to corrosion by weather elements, continues unabated in the transportation industry for trains, trailers, and other conveyances.

Other uses, showing continued satisfaction with the service records of stainless steels, include contractors' products (air conditioning, plumbing, and heating), industrial equipment (chemical, food processing, textile, pulp, and paper), household appliances (stoves, refrigerators, cooking utensils, and tableware), and many others.

● **High temperature alloys.** The need for materials to withstand the exceptionally high temperatures of jet and gas turbine engines has given great impetus to the development of so-called "superalloys" for high temperature service, and as the demand for such engines becomes popular, a considerable market for these materials may be anticipated.

● **Alloy cast irons.** Industry is paying increasing attention to the engineering characteristics of alloy irons. Of note are the high strength gray cast irons containing 1½ to 5 per cent nickel, which are being used in diesel engine crankshafts and cylinder liners and for aircraft piston rings. Strength up to 100,000 lb. per sq. in. are being obtained.

Modern high duty cast irons contain up to 38 per cent nickel. A low expansion type of cast iron containing from 36 to 38 per cent nickel is an important component in high precision machine tools. The abrasion-resisting martensitic cast irons containing 4½ per cent nickel are rendering excellent service and are finding widespread use in steel mills, and the mining, cement, ceramic, power, paint and foundry industries.

● **Cast bronzes.** A new cupro-nickel-aluminum bronze containing 12 per cent nickel, 0.6 per cent iron, 1.0 per cent manganese, and 1.5 per cent aluminum combines superior resistance to salt water corrosion and excellent mechanical properties, including 85 to 95,000 lb. per sq. in. tensile strength. It is expected to find broad usage in marine hardware and ship propellers where high strength and sea water corrosion-resistance are required.

● **High nickel irons.** There has been a marked expansion in the peacetime use of iron-nickel alloys possessing specialized thermal expansion properties as a result of more general use of automatic controls in electrically operated and temperature controlled products. The thermostatic bimetals ordinarily used to actuate these devices employ alloys containing 36 to 42 per cent nickel for the low expansion side and a variety of alloy types containing 20 to 70 per cent nickel for the high expansion side.

A marked increase also has occurred in the use of glass sealing alloy with 29 to 49 per cent nickel for the manufacture of vacuum tubes, high wattage lamps, sealed beam headlights, etc. The unique magnetic characteristics shown by alloys of the group containing 47 to 84 per cent nickel have become particularly important with the increasing use of higher frequency power applications in the electrical industry.

● **Nickel plating.** Nickel plating continues to be an increasing part of expanding platers' activity. Developments in high speed nickel plating baths, permitting the deposition of metal at higher current densities, have increased production capacities of shops with limited tank sizes and floor space. Bright nickel processes are being augmented by "semi-bright" deposits of good buffing qualities to reduce polishing and buffing costs.

The automotive industry, largest consumer of nickel for plating purposes, is employing heavier thickness of the metal to provide a more lasting and durable finish. The application of nickel plating for industrial uses is broadening to include numerous fields other than for decorative purposes. Units of intricate design are electroformed of nickel deposited at high speeds at lower costs than cast or machined products. Nickel plat-

*By the staff of Development and Research Division of The International Nickel Company.

ing to build up undersized dimensions resulting from over-machined or worn surfaces has proved profitable enough to cause the formation of several concerns to provide just this specific service. Electrodeposited nickel coatings on plastic and aluminum articles combine to produce a finished product with the relative advantages of both the base materials and the metallic nickel surface. Heavy nickel plate is providing corrosion resistant surfaces to processing equipment in the food and chemical industries to protect the consumer, improve the quality of the product, and prolong the life of the equipment itself.

● **Nickel and high nickel alloys.** A strong trend toward the use of nickel, Monel, Inconel, and other high nickel alloys for consumer products has become widely evident. Several producers already have resumed the manufacture of Monel kitchen sinks. Corrosion resistant and rustproof hot water storage tanks for gas and electric heaters also are again being made of Monel.

Inconel sheathing units for heating elements of electric kitchen ranges have likewise returned to the market and more than a dozen of the leading manufacturers have standardized on the alloy for this purpose.

In addition to such major applications, there has been a return to nickel as well as Monel for a variety of kitchen household accessories, including nickel lead wires and other electrical applications. A new item is a pot cleaner made of knitted Monel mesh.

There are products for special classes of consumers. For example, manufacturers are now turning out for the fisherman fishhooks, lines, reels, pliers, and similar items of equipment that will not rust in salt water or air.

Wide use by the Navy during the war has stimulated interest in such marine equipment as Monel propeller shafts and other boating accessories.

An important wartime development now being applied to peacetime is precision castings in nickel, Monel, Inconel, and in the heat-treatable alloys such as "S" Monel. These castings make possible the production of intricate shapes and designs, especially in small sizes, without machining.

Still another use of the high nickel alloys is a new welding rod for the making of machinable welds in cast iron. Reports from a wide variety of industries indicate that this rod can salvage annually hundreds of thousands of dollars in castings that otherwise would be scrapped.

Extruded shapes in the alloys—not available prior to the war—are now being produced on a large scale. There is also in evidence an expansion in the use of nickel-clad, Monel-clad, and Inconel-clad steel. Nickel-clad steel, among other applications, has begun to replace wood and steel cellar equipment and is being used in fermenting rooms and elsewhere in breweries. Beer cooler coils of pure nickel are on the market.

★★★

P 094.13

It may be you could use slightly larger rope

E. STYRIS, purchasing agent for the Isbell Construction Company, Reno, Nevada, says that "It is my belief that many manufacturers of heavy equipment of all types are not making sheave and drum grooves large enough. Certainly our experience is proving this."

He clinched his belief by citing an example of two power shovels, both 2½-yd. capacity, both working side by side, doing the same type of work, handling the same type of material, both operated by skilled shovel runners. The only difference between the two outfits was that Shovel A was equipped with 1-in. diam. rope, whereas the sheave grooves on Shovel B had been re-grooved and equipped with 1⅛-in. rope. The two ropes were identical in construction: 6 by 19, Preformed Regular Lay, Improved Plow Steel.

The service records of one run showed that the 1⅛-in. rope, which had been installed on Shovel B, moved a total of 257,967 tons of material, whereas the 1-in. rope on Shovel A turned in a volume of only 112,184 tons.

Styris may have a point here. At any rate his management is currently re-grooving the sheaves and drums on all their equipment (as it becomes necessary) to accommodate a slightly larger wire rope.

Whether or not such a policy could be applied to all cable-operated equipment seems to us debatable; however, it is possible that machine designers are building sheaves and drums to diameters suitable to the old, ordinary, non-preformed wire rope. They may be failing to take into consideration the extreme flexibility of preformed wire rope and its ability to much better withstand bending fatigue.

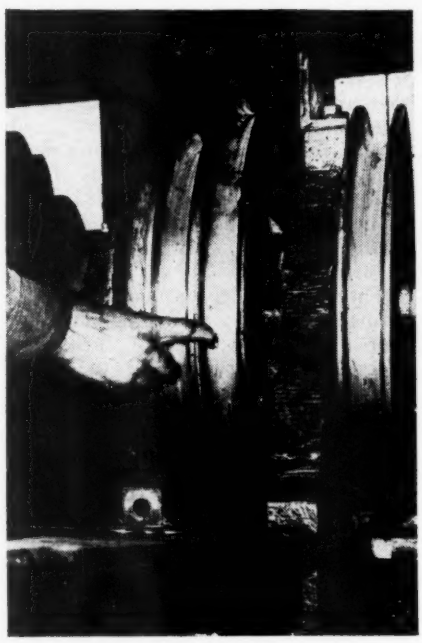
The current table for calculating minimum sheave and drum diameters is:

Table for calculating minimum sheave and drum diameters.

For 6x7 construction	42 times diameter of rope
For 6x19 Seale construction	34 times diameter of rope
For 6x16 filler wire construction	30 times diameter of rope
For 6x19 Warrington construction	30 times diameter of rope
For flattened strand	30 times diameter of rope
For 8x19 Seale construction	26 times diameter of rope
For 6x19 filler wire	26 times diameter of rope
For 6x22 filler wire	23 times diameter of rope
For 8x19 Warrington	21 times diameter of rope
For 8x19 filler wire	21 times diameter of rope
For 6x37 Seale	18 times diameter of rope
For 6x41	18 times diameter of rope

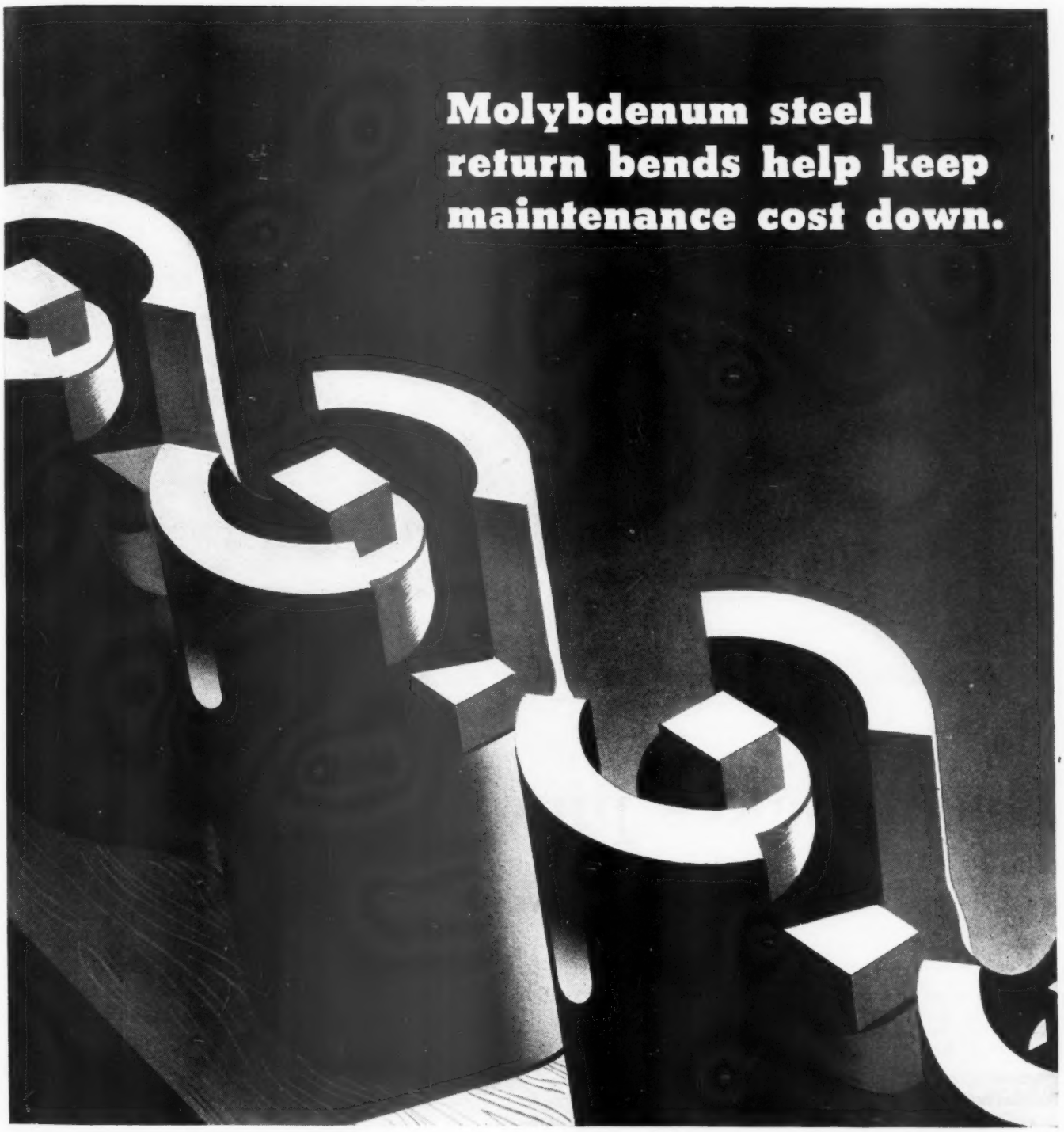
This table, originally scaled for ordinary, non-preformed wire rope, has been used for uncounted years. Actually it is obsolete so far as preformed is concerned as proved by Styris' recent parallelism. In his case the two ropes were, respectively, 1 in. and 1⅛ in. in diam. As the rope construction was 6 by 19 that meant, if the machine designer were to follow the above table literally, the sheave diameter for the 1-in. rope should be 30 in. and the one for the 1⅛-in. rope should be 34 in. in diam. Yet here was a 1⅛-in. rope giving twice the service of a 1-in. rope on a sheave designed for the latter. And all because it had been made more easy to bend by being preformed.

It is only reasonable to believe that when endowed with flexibility a larger diameter and stronger rope will far outlast a smaller rope. Because at the present time more than half of all the wire rope made and used in the United States is preformed what really needs to be done is for the wire rope industry to formulate a new table for sheave and drum diameters based on preformed's greater flexibility. In the meantime, it might be worthwhile for many operators to consider re-grooving their present equipment to accommodate a larger and stronger rope. Before actually doing so, however, it would be better to consult a wire rope engineer.



Sheaves for hoisting line on a 2½-yd. shovel. These were re-grooved to accommodate 1⅛ in. diameter rope instead of the 1 in. originally used. Only preformed wire rope used.

★★★



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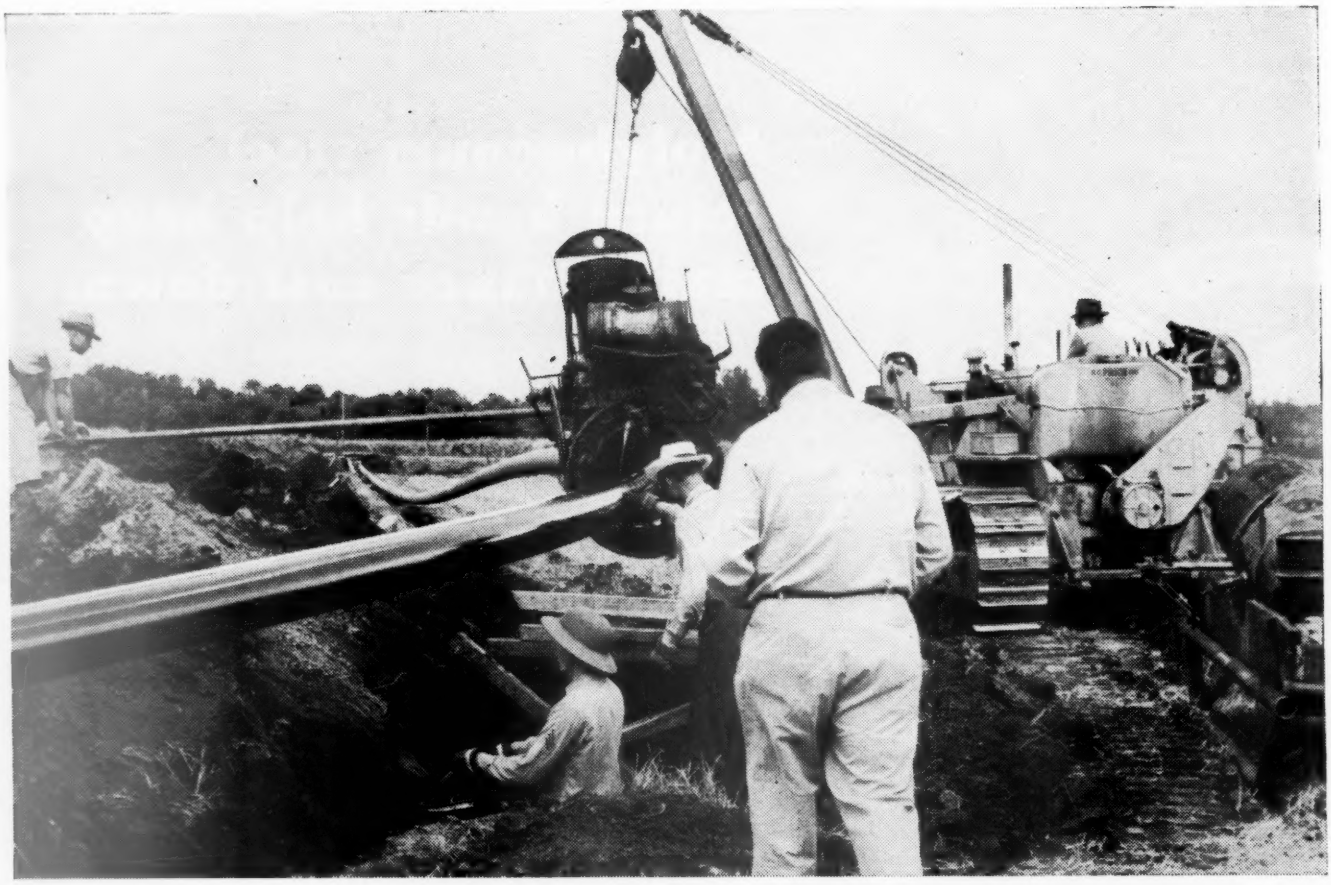


The cleaning and priming machine makes a sharp side bend.

Great Lakes pipe line extension

By **FRANK H. LOVE,** *Managing Editor*

COMPLETION of an extensive expansion program by the Great Lakes Pipe Line Company in five mid-western states extends that company's facilities into an

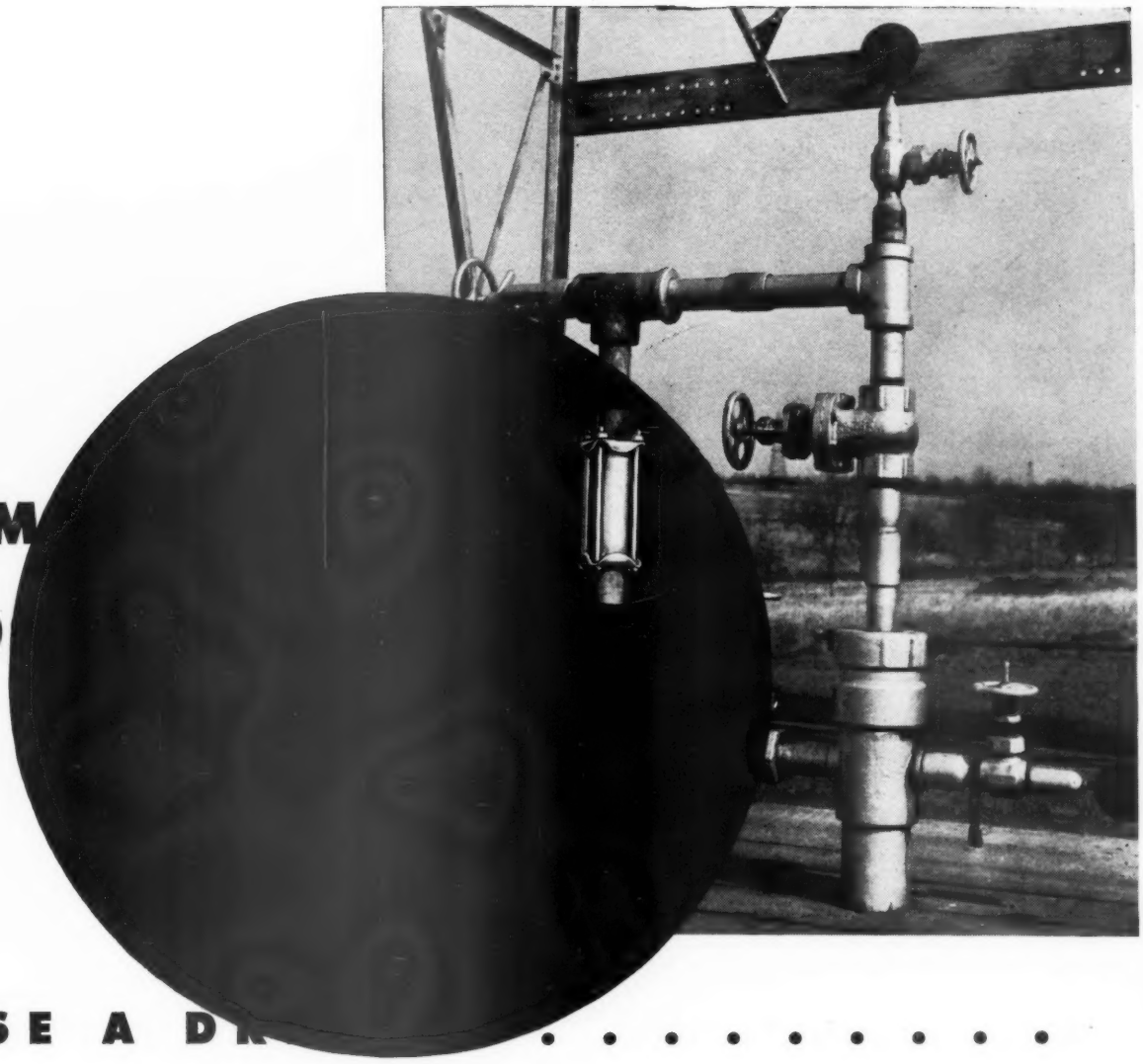
EXCLUSIVE

area not previously served by a products line. Laying of 6-in. and 3-in. pipe from Sioux Falls, South Dakota, to Grand Forks, North Dakota, via Willmar and Alexandria, Minnesota, Fargo, North Dakota, and other intermediate points, was completed this month. Previously, as part of a 600-mile construction program, an 85-mile line was laid between Eldorado and Humboldt, Kansas, and a 205-mile line from Kansas City, Missouri, to Omaha, Nebraska. These two lines were of 8-in. pipe.

Construction of stations and terminals, now under way, will be completed as rapidly as delivery of materials permits.

New terminals are being erected at Watertown, South Dakota; Marshall,

Testing for holidays after pipe has been coated and wrapped.



TO M

END

USE A DR

What do you do with a hookup when pipe ends don't quite meet?

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"Use a Dresser", they'll tell you.

The Dresser Long Coupling (Style 40) shown here is what they mean. It will make a permanently tight, vibration-proof joint even if the pipe ends are several inches apart and out of line.

Specially compounded rubber gaskets, squeezed between follower rings and a long middle ring or body, provide a flexible, high-pressure "pack" around both pipe ends. All parts are factory-built and tested, then assembled and delivered to you complete—ready to install.

Get them from your oilfield stores who can get overnight service throughout the southwest from our Houston Warehouse. Write for complete information.

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COUPLINGS

Shield protects electric arc from wind when making weld.

Willmar, Alexandria, and Mankato, Minnesota; Fargo and Grand Forks, North Dakota. At each terminal 320,000 bbl. of storage facilities will be provided, as well as a motor transport loading rack, a railroad loading rack, service buildings, and other auxiliary facilities.

The pumping stations are being spaced at about 45-mile intervals. Capacity of the line will be approximately 30,000 bbl. a day.

The course of the last "leg" of the line is northeast from Sioux Falls to Alexandria, Minnesota, where it turns northwest to Fargo, North Dakota, and from that point extends due north to Grand Forks, North Dakota.

The pipe was primed and coated in the field, using a coal tar enamel having a 190°F. melting point. Application was with a two-headed machine that gave a double coating to the pipe and at the same time wrapped it with 15-lb. tar saturated asbestos felt. Minimum thickness of the coating was 5/32 in. After the pipe was coated and wrapped, a rolled-coil spring-type holiday detector was run to locate any faults in the coating.

Pipe joints were electrically welded and all major rivers and streams were crossed by suspension bridges. H-frames were used to support pipe over small draws, ravines, and peat bogs.

A drag attached to the ditching machine served to square the bottom of the ditch and pipe was laid with a minimum of 24 in. of covering.

The line was air-tested to 100 lb. while under construction, in sections varying in length from three to five miles. When completed, hydraulic pressure of 1000 lb. was applied to the line for a period of 24 hours. The 6-in. section of the line was completed first, and while the 8-in. was under construction, air pressure was held on the former with recording pressure gauges installed at both ends of the section. This was in order to tell immediately should the line be cut into either by accident or design.

Rapid time was made in constructing the line, the average amount of pipe laid per day being about four miles.

Harry A. Moreland is president of the Great Lakes Pipe Line Company, which has its headquarters in Kansas City, Missouri. Supervising the construction work were C. C. Keane, chief engineer, and W. T. Pyott, assistant chief engineer. The company's key field personnel on the northern section were J. R. Ellis, district engineer, O. J. Dodgion, A. R. Fulcher and C. W. Yandell, chief inspectors.

H. C. Price Company, Bartlesville, Oklahoma, was the general contractor for the northern section of the Great Lakes Pipe Line Company's major expansion program, which involved the laying of more than 385 miles of pipe line in the states of Minnesota, North and South Dakota. J. P. Neill, vice president, and C. S. LeNoir, general superintendent, supervised the overall construction work.

Construction of the first section, comprised of approximately 180 miles of 6-in. line running from Alexandria, Minnesota, to Fargo and Grand Forks in North Dakota, was completed with two spreads made up of the following key personnel:

Spread No. 2—R. K. Shivel, superintendent; Roy Burgess, office manager; and these foremen: J. D. White, right-of-way; W. R. Flanagan, ditch; Clarence Shivel, pipe; R. L. Ezell, welding; G. E. Beavers, paint; D. D. Canfield, lower-in; J. A. Hairston, backfill and clean-up.

Spread No. 3—W. B. Williams, super-

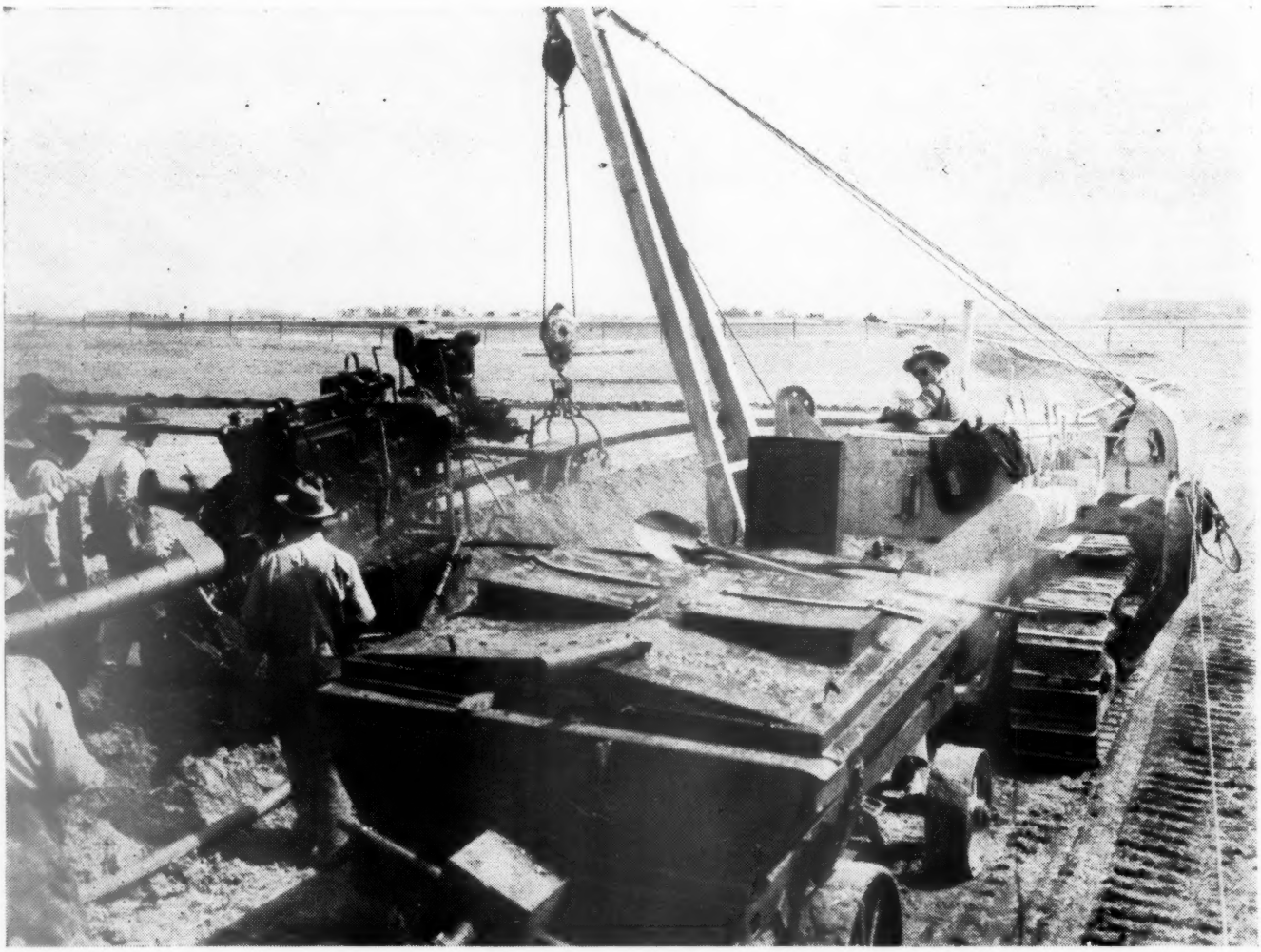
Numerous supports of this type were used to suspend the pipe line over ravines, narrow creeks, etc.

Merry Christmas

May the holiday season bring you the peace of mind that is symbolized by the gleam of a burning candle. May you and yours enjoy, throughout 1947, the glow of radiant health. May the coming year be all that you want it to be. This is the sincere Christmas wish of the makers of

GASO PUMPS

for every oil industry need



Coating and wrapping the pipe near Grand Forks, North Dakota.

Sideboom tractor holds pipe as it is shoved beneath railroad tracks.

intendent; P. O. Rutledge, office manager; and these foremen: D. L. Beachy, right-of-way; K. K. Kelly, ditch; Chester Kinkead, pipe; Chas. F. Jones, welding; A. G. Hobson, paint; H. C. Morrison, lower-in; A. D. Hamilton, backfill and clean-up.

The second section originally called for the construction of 142 miles of 8-in. line beginning at Sioux Falls, South Dakota, and ending near Willmar, Minnesota. Spread No. 2 under the direction of R. K. Shivel was used on this job until the middle of September, at which time the H. C. Price Company was awarded an additional contract for the construction of approximately 63 miles of 8-in. pipe between Willmar and Alexandria, Minnesota. Spread No. 4 was then started working south from Alexandria. This spread was made up of the following key personnel:

Spread No. 4—A. T. Beaman, superintendent; W. R. Crego, office manager, and these foremen: J. H. Latham, ditch; J. E. Glenn, pipe; Charley E. Ross, welding; A. D. Hamilton, paint; Ray Abney, lower-in; L. C. Armstrong, backfill and clean-up.

On the work completed earlier in the year, the contractors were A. C. Holder Construction Company and Williams Brothers Corporation for the section of line between Eldorado and Humboldt, Kansas; and Williams Brothers Corporation and Midwestern Engineers for the line from Kansas City to Omaha. ★ ★ ★

HASTELLOY TRADE-MARK Alloy is Readily Fabricated

High-strength HASTELLOY alloy is widely used throughout the chemical industry because of its outstanding resistance to severely corrosive media. It is available in standard mill forms that can be fabricated by most usual methods. For information on properties, forms, and applications, write to any district office.

OXY-ACETYLENE WELDING

HASTELLOY alloy processing equipment can be readily fabricated by oxy-acetylene welding. Here a flange is being welded on a HASTELLOY alloy tank outlet.

ELECTRIC ARC WELDING

Large equipment made of HASTELLOY alloy is assembled by metallic arc, atomic hydrogen, or HELIARC welding. Shown here is a 1,000-lb. water jacketed cooler inlet sleeve for handling sulphur dioxide solutions.

MACHINING

The machinability of HASTELLOY alloys A, B, and C facilitates the manufacture of a wide variety of parts such as the alloy C pump back shown here.

GRINDING

HASTELLOY alloy D can best be finished by grinding. These small alloy D pins are being finished to very close tolerances on a centerless grinding machine.

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Effect of the crude gravity on the performance of gas drive reservoirs

By **MORRIS MUSKAT** and **M. O. TAYLOR,** Gulf Research and Development Company

● **Summary.** Calculations have been made on the performance of solution gas drive reservoirs as a function of the gravity of the crude produced. The P-V-T properties of the natural gas and oil as functions of the crude gravity were taken from correlations with the crude gravity previously established by Katz and Beal. It is shown that the ultimate free gas saturation developed during pressure depletion increases uniformly with increasing API gravity of the crude. The ultimate recovery, as a fraction of the initial oil content, also increases with the API gravity, although the curve flattens at the higher gravities. The absolute recovery, expressed as a fraction of the pore space, shows a maximum at about 40-deg. API crude gravity. The maximum gas-oil ratio developed during the production history is greatest for the 10-deg. API gravity crude, falls to a minimum at about 22-deg. API gravity, and rises again uniformly with increasing crude gravity. The productivity index, at depletion, expressed as a fraction of its initial value, decreases with increasing crude gravity. These results are interpreted as a composite effect of gas solubility, oil viscosity, and shrinkage, in which the viscosity is the predominating factor at low gravities and the shrinkage plays a major role in determining the recovery of the crudes with gravities higher than 40-deg. API. In all cases the same permeability saturation curve was used, with an assumed gas equilibrium saturation of 10 per cent. The connate water saturation was assumed to be 25 per cent in all cases.

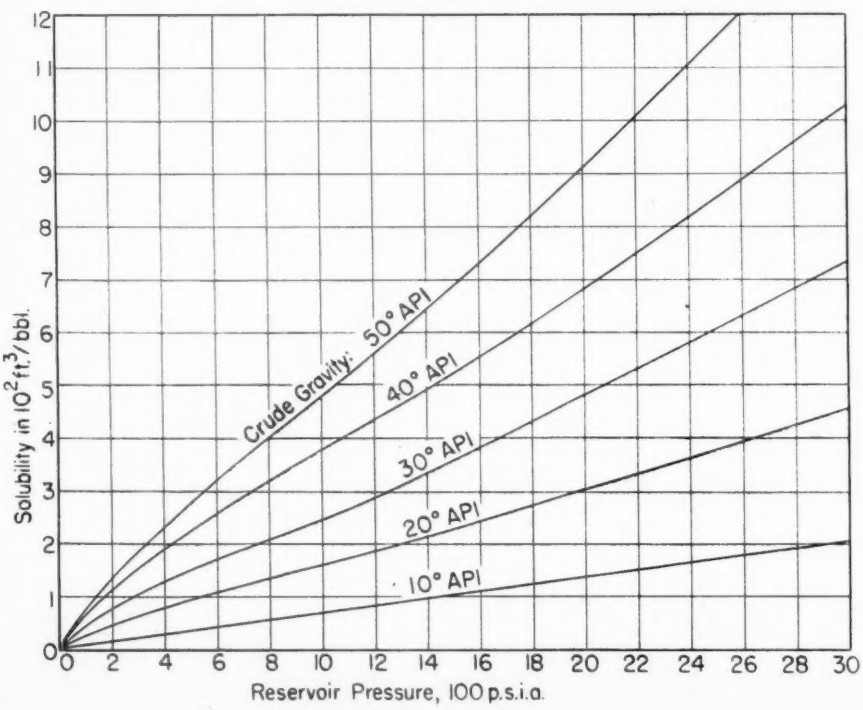
EXCLUSIVE

● **Introduction.** In a recent paper[1] were given the results of calculations on the theoretical behavior of ideal solution gas drive reservoirs, as it may be affected by the various fluid and rock properties. These included the effects of oil viscosity, gas solubility, oil shrinkage, size of gas cap, amount of connate water, and details of the gas to oil permeability ratio curve. In order to bring out most clearly the individual effects of these properties, the calculations were made under conditions where the different physical parameters were varied separately, the remaining functions of pressure and oil saturation being kept fixed. With respect to the role played by the shrinkage of the oil, calculations were also made in which the amount of shrinkage was varied in proportion to changes in the gas solubility, for the two are obviously intimately related.

The results of these calculations were largely those to have been expected on the basis of general considerations. For example, the ultimate recovery was found to decrease uniformly with increasing crude viscosity. It increased with increasing size of gas cap; and when the solubility alone was varied the ultimate recovery increased with increasing amounts of gas in solution. The role played by the shrinkage turned out to be of major importance, however, so that when the shrinkage was taken as increasing simultaneously with the gas solubility, the resultant recovery was found to decrease ultimately as the amount of gas in solution was increased. Moreover, because of the shrinkage effect, the computed percentage recovery of initial oil in place decreased with decreasing amounts of connate water.

Although these studies have served to indicate the separate effects of the various features controlling the performance of gas drive reservoirs, they do not show directly the behavior to be expected of actual crude oil producing fields. To make predictions of the histories of specific reservoirs, numerical data pertaining to the particular systems of interest would have to be used and the calculations repeated for each case. On the other hand, it is possible to derive the gross features of general gas drive reservoir performance by characterizing the nature of the fluids produced by means of the gravity of the crude oil. Although the crude gravity is not alone a unique and precise index of the thermodynamic properties of reservoir fluids, it does provide at least a semi-quantitative means of correlating these properties. Early

FIG. 1. Gas solubility vs. pressure, at reservoir temperature, assumed for different API gravity crudes.


Solubility in 10^{-2} ft.^{3}/bbl.
Crude Gravity: 50° API
40° API
30° API
20° API
10° API
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Reservoir Pressure, 100 p.s.i.a.

[1] M. Muskat and M. O. Taylor, *AIME Petroleum Technology 8*, 1-16, September, 1945.

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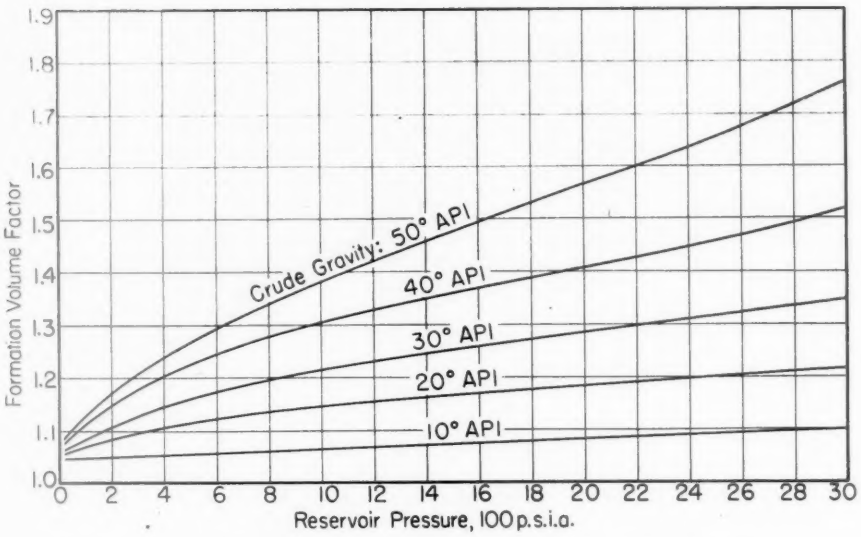


FIG. 2. Formation volume factor for liquid phase vs. pressure at reservoir temperature assumed for different API gravity crudes.

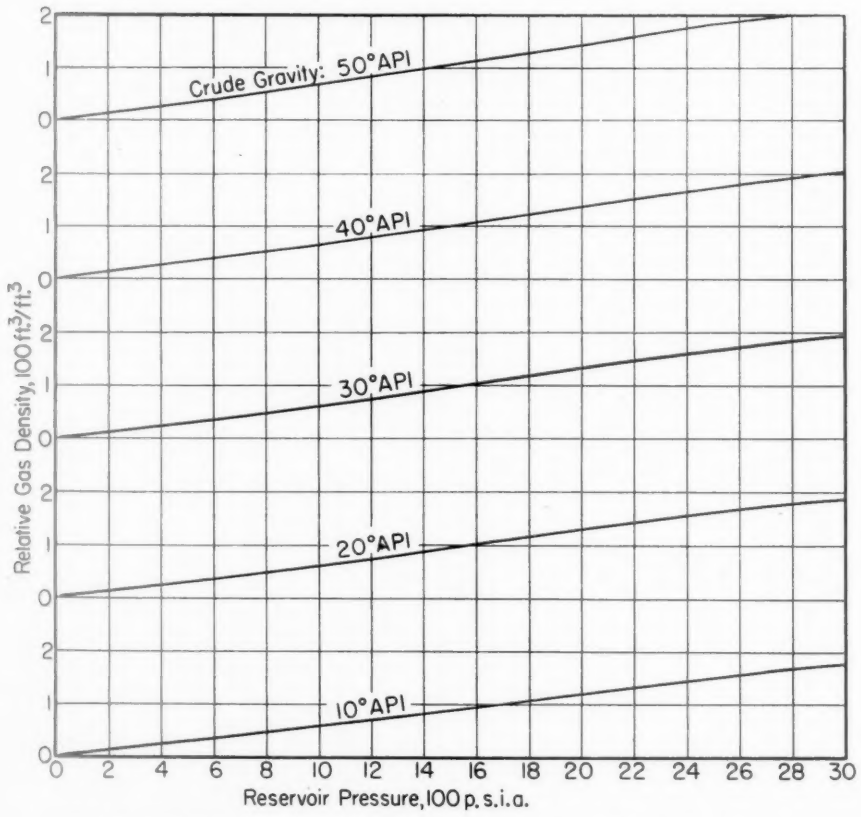


FIG. 3. Relative gas density vs. pressure, at reservoir temperature, assumed for gas liberated from various API gravity crudes.

work of Katz[2], and a recent study by Beal[3] have shown that the P-V-T properties of crude oil and natural gas systems can be correlated with the crude oil gravity. Although in individual instances the correlation charts prepared by Katz and Beal may be in error by as much as 15 to 25 per cent, statistically, they appear to be valid to a fairly high degree of accuracy. Accordingly, systematic calculations were made of theoretically expected production histories of gas drive reservoirs as functions of the crude oil gravity. The basic fluid properties, as the gas solubility, oil shrinkage, gas density, and oil viscosity were taken, for each crude gravity, from the charts of Katz and Beal, although in some cases smoothing and adjustment of data were necessary. The data as actually used and the results of the calculations are presented in the following sections.

● **Basic reservoir data.** The solubility curves as functions of the reservoir pressure, used in the calculations reported here, are plotted in Fig. 1. These are equivalent to the curves given by Beal (Fig. 10) except for a smoothing of the data in the neighborhood of 1000 psi connecting Beal's curves on the reduced and expanded scales.

The formation volume factors, as functions of the reservoir pressure, which were used in the calculations are plotted in Fig. 2. The terminal points at 3000 psia, which represents the initial reservoir pressure assumed in all the calculations, were taken from shrinkage vs. solubility correlation charts of Katz (Fig. 6). The terminal points at atmospheric pressure were taken from the thermal expansion chart of Katz (Fig. 5), assuming a reservoir temperature in every case of 190°F. The data for immediate pressures were simply drawn in so as to simulate the types of curves commonly found in bottom hole sampling or surface recombination analysis.

The relative gas densities used in the calculations are plotted in Fig. 3. These were obtained as follows: The gravity of the liberated gas as a function of the crude gravity was determined from the gravity vs. solubility chart of Katz (Fig. 7). It was assumed that this gravity remained substantially the same throughout the pressure depletion range*. Using these gravities for each crude oil, the relative density as a function of pressure was then calculated by the Standing and Katz[4] charts to determine the deviation factors of the gas as corrections to the Boyle's law perfect gas density.

The variation with pressure of the fluid reservoir viscosity ratio, assumed for the calculations, is plotted in Fig. 4. The gas viscosity, as a function of pressure, was determined from the correlation charts of Bicher and Katz[5] as converted to a gas gravity scale by Beal (Figs. 5 and 6). The crude oil viscosities at atmospheric pressure and 190°F. were obtained by reference to Fig. 8 of Beal. The viscosity of the gas saturated oils at various reservoir pressures was then determined by reference to Fig. 9 of Beal, making use of the solubility curves of Fig. 1. The resulting ratios so found are plotted in Fig. 4.

To apply these basic data to the calculation of reservoir performance curves certain derived functions must first be

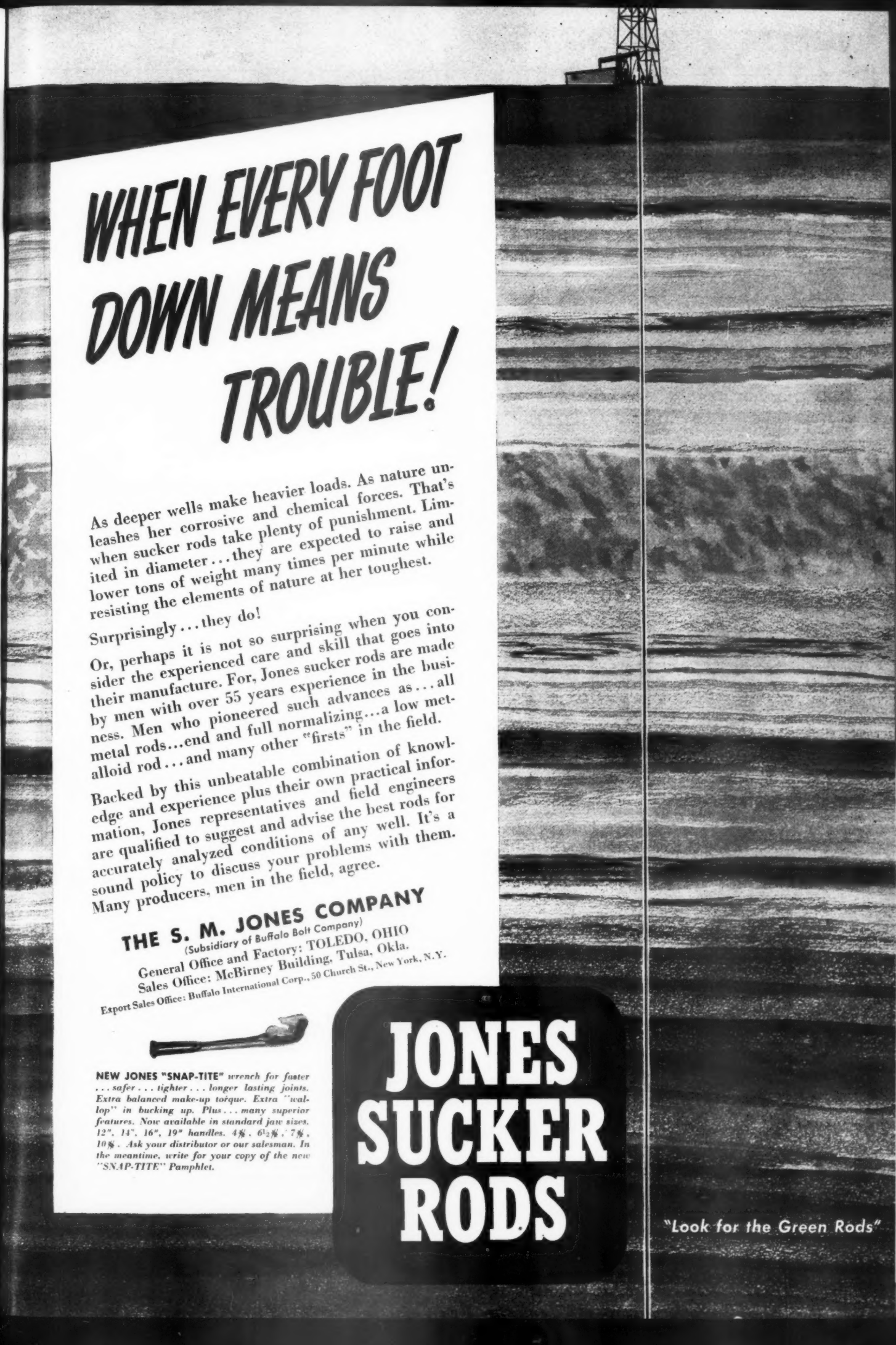
[2]D. L. Katz, *API Drilling and Production Practice*, 137-47 (1942).

[3]C. Beal, *AIME Petroleum Technology 9*, 1-22, March, 1946.

*This assumption will, of course, seldom be strictly valid. It will be least satisfactory at low pressures and for the higher gravity crudes; however, the average values given by the Katz chart should not cause serious errors in the results, for the integral of the basic equation (2) is not sensitive to the exact form of the gas density function.

[4]M. B. Standing and D. L. Katz, *AIME Petroleum Development and Technology 146*, 140-9 (1942).

[5]L. B. Bicher, Jr. and D. L. Katz, *AIME Petroleum Development and Technology, 155*, 246-52 (1944).



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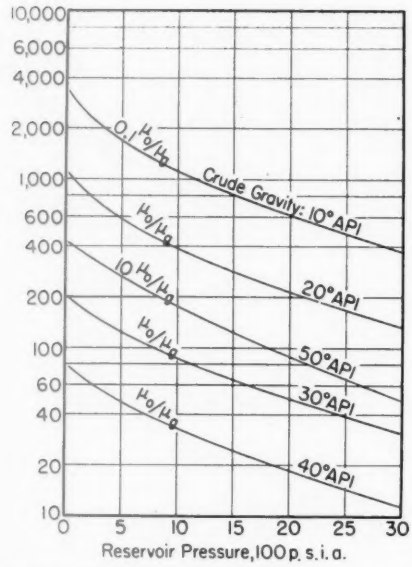


FIG. 4. The ratio of the oil to gas viscosity, μ_o/μ_g, at reservoir temperature, assumed for different API gravity crudes.

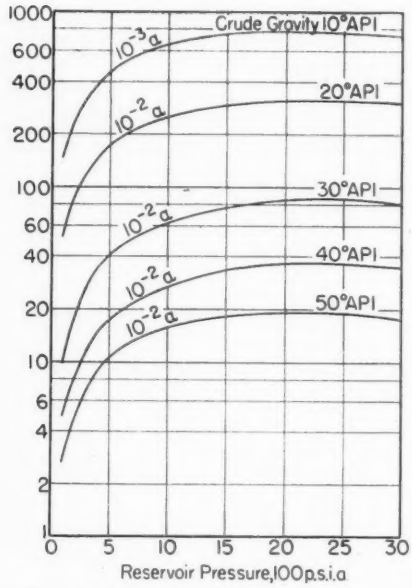


FIG. 5. Variation of composite function $\alpha(\rho)$, at reservoir temperature, with pressure for different API gravity crudes.

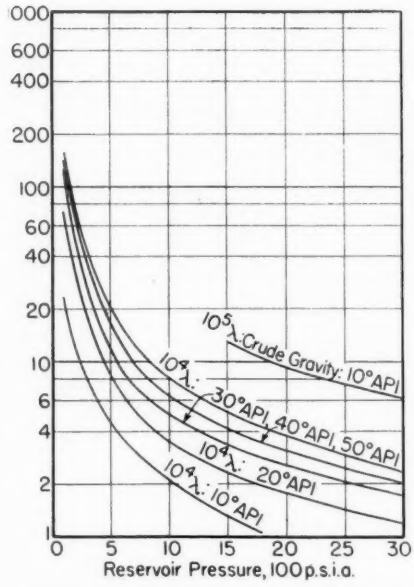


FIG. 6. Variation of the function $\lambda(p)$, at reservoir temperature, with pressure for different API gravity crudes.

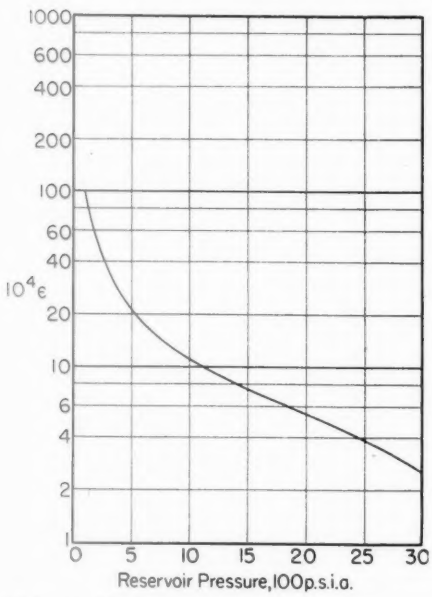


FIG. 7. Variation of the function $\xi(p)$, at reservoir temperature, with pressure for different API gravity crudes.

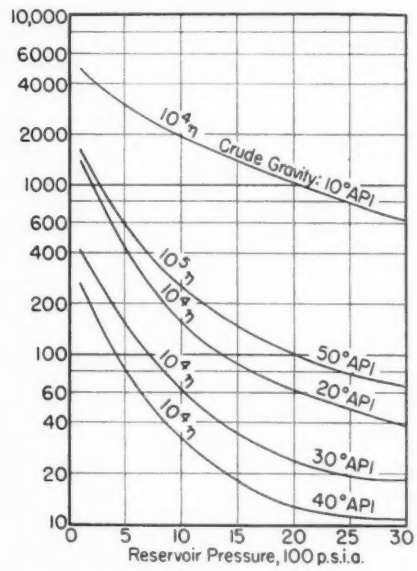
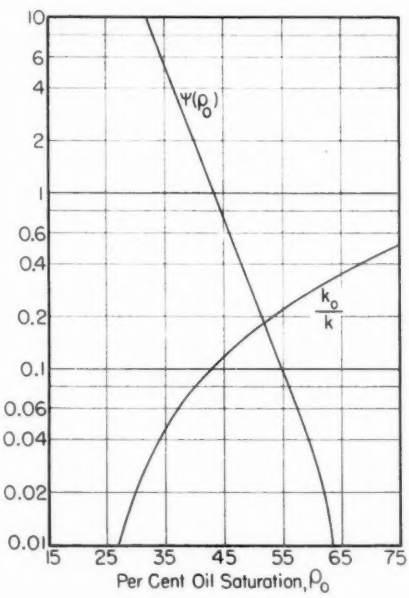


FIG. 8. Variation of the function $\eta(p)$, at reservoir temperature, with pressure.



$$\psi(\rho_o) = \frac{\text{Permeability to gas}}{\text{Permeability to oil}}.$$

$$\frac{k_o}{k} \quad \frac{\text{Permeability to oil}}{\text{Homogeneous fluid permeability}}$$

Connate water saturation (assumed) = 25%

Equilibrium gas saturation (assumed) = 10%.

FIG. 9. Permeability ratio function and relative permeability to oil assumed for calculating gas drive histories for different API gravity crudes.

evaluated. These may be defined by the equations:

$$\alpha(p) = \frac{\gamma\beta\mu_o}{\mu g}\,;\ \lambda(p) = \frac{1}{\gamma\beta}\frac{dS}{dp}\,;\ \xi(p)$$

$$= \frac{1}{\gamma}\frac{d\gamma}{dp}\,;\ \eta(p) = \frac{\mu_o}{\beta\mu_g}\frac{d\beta}{dp}\,. \quad . \quad (1)$$

Where:

γ = the relative gas density as plotted in Fig. 3,

β = the formation volume factor of the oil as plotted in Fig. 2,

μ_o/μ_o = the ratio of oil to gas viscosity shown in Fig. 4, and

S = the gas solubility, such as plotted in Fig. 1.

From the curves of Figs. 2, 3, and 4 values of α were calculated, and the results so found for the different crude oil gravities are plotted in Fig. 5. The value of $\lambda(p)$, as obtained by taking the derivatives of the curves of Fig. 1, and combined with the data of Figs. 2 and 3, are plotted in Fig. 6. The values of $\xi(p)$, as derived from the curves of Fig. 3, were found to be almost identical for the dif-

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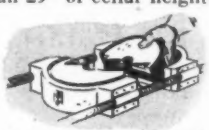

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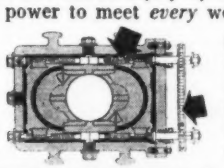

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ferent crude gravities, within the inherent uncertainties in the basic data. Accordingly, a single average curve, as plotted in Fig. 7, was used for all the crude gravities. By combining the curves for α with the data plotted in Figs. 2 and 3, values for the function $\eta(p)$ were determined. These are plotted for the different crude gravities in Fig. 8.

The curves of Figs. 4 to 8 provide the resultant reservoir fluid data required for the calculation of gas drive reservoir performance. The actual calculations were made by a numerical integration of the previously developed[6] differential equation, namely:

$$(1+\frac{\mu_o}{\mu_g}\psi)\frac{d\rho_o}{dp} = \rho_o\lambda + (1-\rho_w-\rho_o)\,\xi + \rho_o\eta\xi,$$

$$R = S + \alpha\psi(\rho_o), \quad \ldots\ldots \quad (2)$$

in which it is assumed that the reservoir is subject neither to gravity drainage nor

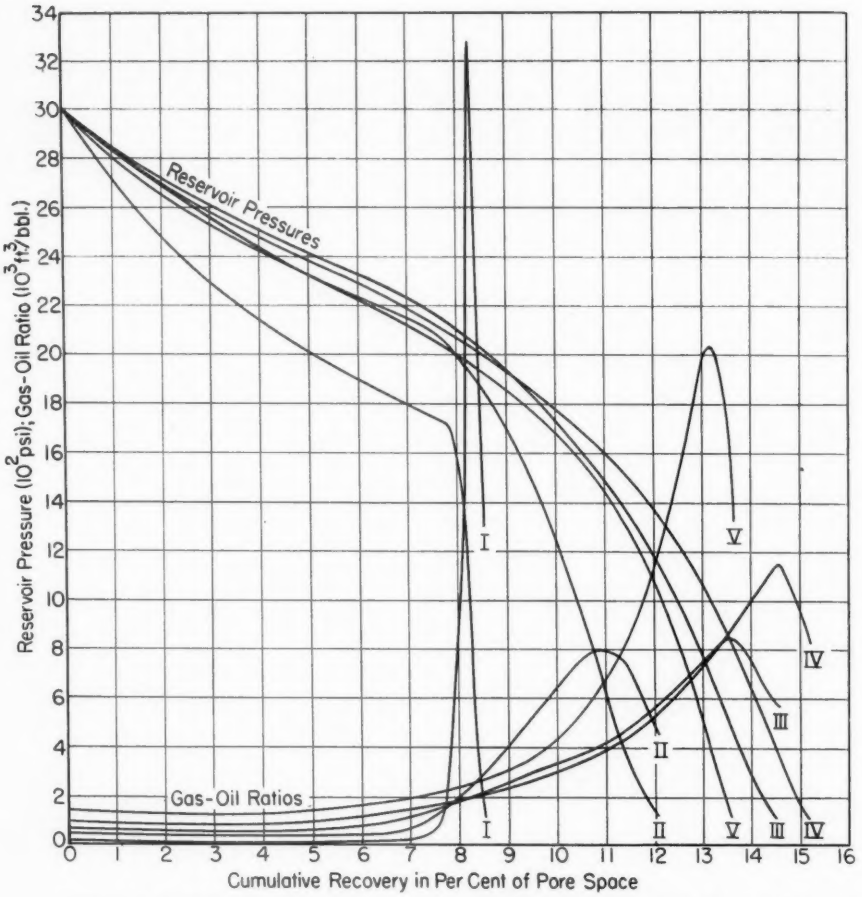


FIG. 10. Calculated pressure and gas-oil histories of gas drive reservoirs producing different API gravity crudes. Curves I: 10° API; Curves II: 20° API; Curves III: 30° API; Curves IV: 40°; Curves V: 50° API.

[6]M. Muskat, *J. App. Physics, 16,* 147-59 (1945). It may be noted here that in this paper, equation (12), and in that of Muskat and Taylor (loc. cit.) equation (5), should be corrected by striking out γ from the coefficient of $\frac{d\beta}{dp}$. This typographical error affected in no way the numerical or general conclusions given in either paper, as the whole term involved dropped out in each case. In addition, however, the solubility of the gas in the residual oil in the gas cap was neglected. The correct equation taking this into account is:

$$\frac{d\rho_o}{dp} = \frac{\rho_o\lambda + (1-\rho_w-\rho_o)\,\xi + \rho_o\eta\left(\psi-\frac{rR}{\alpha}\right) + \overline{H}\left\{(1-\rho_w-\bar{\beta}\bar{\rho}_{oi})\,\xi - \bar{\rho}_{oi}\frac{d\beta}{dp} + \bar{\rho}_{oi}\beta\lambda\right\}}{1+\frac{\mu_o}{\mu_g}\left(\psi-\frac{rR}{\alpha}\right)}$$

in the notations of equations (1) and (2), and with $\overline{H}$ the ratio of gas cap to oil zone thicknesses, r the fraction of produced gas returned, and $\bar{\rho}_{oi}$ the residual stock tank equivalent oil saturation in the gas cap.

FIG. 11. Calculated ultimate recovery, free gas saturations, and maximum gas-oil ratios of gas drive reservoirs as functions of crude gravity.

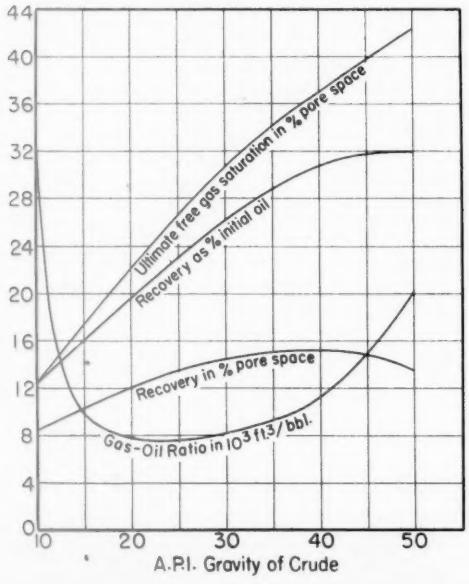
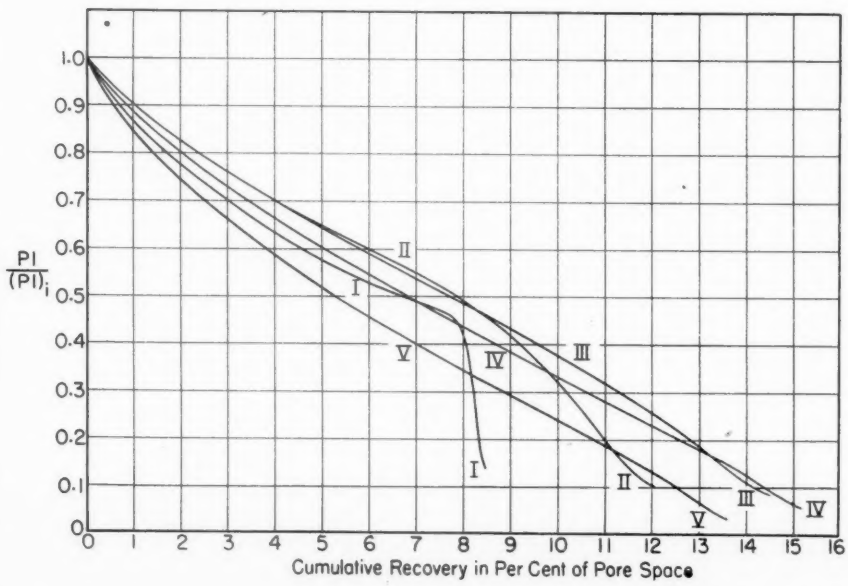

Ultimate free gas saturation in % pore space
Recovery as % initial oil
Recovery in % pore space
Gas-Oil Ratio in 10^3 ft^3/bbl.
A.P.I. Gravity of Crude

FIG. 12. The calculated productivity index variations in gas drive reservoirs producing different gravity crudes, as functions of the cumulative recovery.

$$\frac{PI}{(PI)_i} = \frac{\text{Current Productivity Index}}{\text{Initial Productivity Index}}$$

Curves I: 10° API; Curves II: 20° API; Curves III: 30° API; Curves IV: 40° API; Curves V: 50° API.



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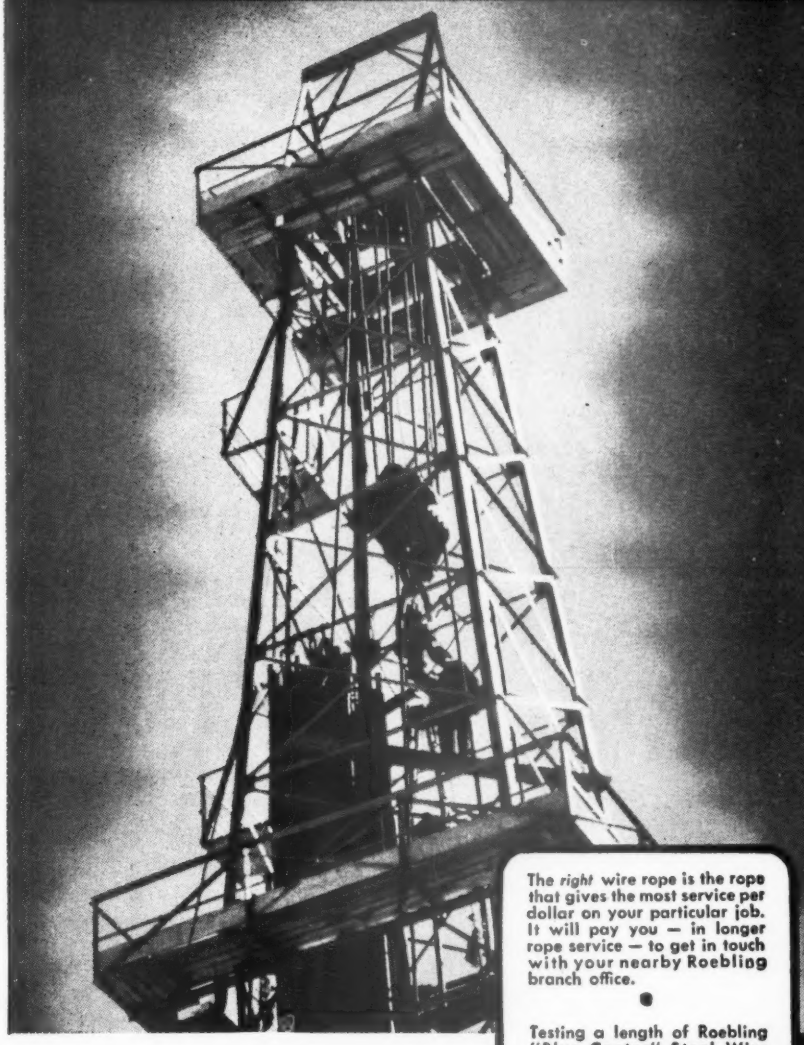

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In equation (2), ρ_o is the oil saturation at any reservoir pressure, and the connate water saturation is ρ_w. R is the producing gas-oil ratio at any state of reservoir depletion and pressure, and the function ψ (ρ_o) is the ratio of the permeability to gas to that of oil. In all the calculations the connate water saturation was taken as 25 per cent. Moreover, the permeability ratio ψ (ρ_o) was taken in all cases to be that given in Fig. 9, the curve being considered as approaching zero at an oil saturation of 65 per cent, which implies an equilibrium free gas saturation of 10 per cent. The relative permeability to oil, to which reference will be made later, is also plotted in Fig. 9.

● **Results.** The results of the calculations are plotted in Figs. 10 to 12. In Fig. 10 are shown the pressure and gas-oil ratio histories of the reservoirs producing the different crude gravities, as functions of the cumulative oil recovery, expressed as a fraction of the pore space, i.e. by the equation:

Cumulative recovery =

$$\left(\frac{\rho_o}{\beta}\right)_1 - \rho_o/\beta \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where $(\rho_o/\beta)_1$ is the initial stock tank oil saturation.

The curves of Fig. 10 are all similar to those obtained previously for gas drive reservoirs, except for the curves 1 referring to a 10-deg. API gravity crude. For the latter the pressure and gas-oil ratio variation initially follows the same general trend as for the higher gravity crudes. After a cumulative recovery of 7.83 per cent of the pore space, however, the pressure drops almost vertically, and the gas-oil ratio rises almost vertically to a maximum far greater than that for any of the other crudes. The reason for this apparently peculiar behavior becomes clear when it is noted that the cumulative recovery of 7.83 per cent of the pore space corresponds to the development of 10 per cent free gas saturation, which is the equilibrium value assumed in the extension of the permeability ratio curve shown in Fig. 9. Up to this point ψ (ρ_o) = O, and the fluid viscosity term drops from equation (2). Accordingly, in this region the reservoir behavior is essentially the same for all the crudes, except for the direct effect of the solubility and oil shrinkage. As soon as the equilibrium free gas saturation is developed, however, the oil viscosity immediately comes into play. The very high viscosity of the 10-deg. crude then leads to an extremely high mobility of gas relative to the oil, and a correspondingly rapid depletion of the reservoir gas. The sharp decline in reservoir pressure and steep rise in gas-oil ratio are thus natural consequences of the very large contrast between the gas and oil mobility after the gas saturation exceeds its equilibrium value. Of course, if no equilibrium free gas saturation had been assumed, the high oil to gas viscosity ratio would come into play at the very beginning of production, and the gas-oil ratio would immediately develop a very rapid rise, with a corresponding fast fall in pressure, finally resulting in a very greatly reduced ultimate recovery. In fact, the calculations as made show that the additional recovery obtained in the case of the 10-deg. gravity crude after the gas first becomes mobile, is only 0.64 per cent, or 7.6 per cent of the total recovery†.

The ultimate recovery at 100 psia, the ultimate free gas saturation, and the maximum gas-oil ratio are plotted as functions of the API gravity of the crude in Fig. 11. It will be noted that the ultimate free gas saturation, in per cent of the pore space, increases continuously with increasing API gravity. This, of course, is merely a reflection of the decreased oil viscosity and increased gas solubility associated with the high gravity crudes. The recovery as a fraction of the initial stock oil in place also increases continuously with increasing gravity, although a marked flattening of the curve develops at a gravity higher than 40-deg. API. This flattening is the result of the increasing role played by the oil shrinkage as the crude gravity is increased, and the associated tendency

†Separate calculations for the 10-deg. API crude, using the permeability ratio curve of Fig. 9 extended to zero for an oil saturation of 75 per cent—no equilibrium gas saturation—gave a total recovery to 100 psi of only 0.86 per cent.

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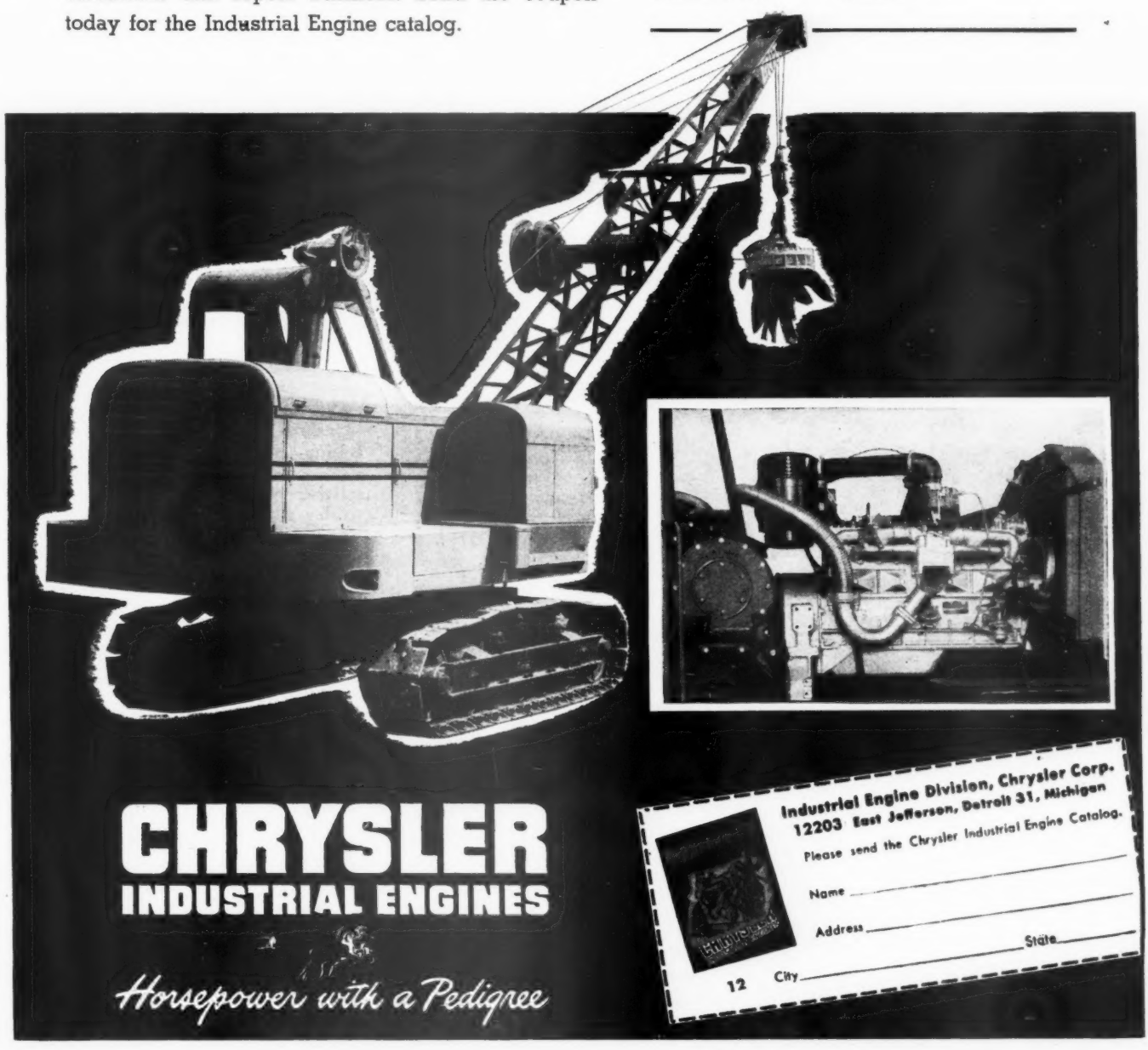

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for a decrease in the absolute value of the recovery. This effect is strikingly shown in the curve for the recovery expressed as a fraction of the pore space, where it is seen that a maximum absolute recovery is reached at approximately 40-deg. API, with lesser recoveries for the higher and lower gravity crudes. This result, which appears anomalous at first glance, was indicated by the previously published calculations in which the shrinkage factor for the oil and gas solubility were increased simultaneously. Here the higher gravity crudes enjoy the advantages of both increased gas solubility and lower oil viscosity; however, the associated increase in shrinkage is still sufficient to counterbalance the favorable factors and lead ultimately to lower absolute recovery values. It is clear, therefore, that in the case of the high gravity crudes the oil shrinkage is the controlling factor determining the oil recovery. This also suggests that in such reservoirs pressure maintenance and prevention of oil shrinkage in the reservoir should be especially beneficial.

The curves for the maximum gas-oil ratios plotted in Fig. 11 also reflect the interplay between the factors of gas solubility, oil viscosity, and shrinkage. The extremely high values in the low gravity range already have been explained as the direct result of the very high contrast between oil and gas mobility that comes into play as soon as the equilibrium free gas saturation is developed. The rising trend in the gas-oil ratio curves at higher gravities is mainly a reflection of the increasing gas solubility in the higher gravity crudes. The region of the minimum of the curve represents the range of gravity in which the factors of oil viscosity and gas solubility are approximately in balance in their effect on the relative rate of gas production.

The decreases in productivity index for the various reservoirs producing different crude gravities are plotted in Fig. 12. To eliminate the uncertainties associated with theoretical calculations of the absolute productivity index, only the relative magnitudes—in the limit of vanishing pressure differential—as compared to the initial values, are plotted. These were calculated by means of the equation:

$$\frac{PI}{(PI)_i} = \frac{(k_o/k)/\mu\beta}{\{(k_o/k)/\mu\beta\}_i} \quad . \quad . \quad . \quad (4)$$

where k_o/k is the relative permeability of oil as a function of the oil saturation, as plotted in Fig. 9, and the subscript i indicates the initial value. It will be seen that in all cases the productivity index will ultimately fall to less than 15 per cent of its initial value. Moreover, the final value reached at 100 psia decreases continuously with increasing crude gravity. This relationship is evidently to be correlated with the decreasing residual oil saturation with increasing crude gravity, as implied by the gas saturation curve of Fig. 11. As the changes in viscosity and formation volume factors between 3000 and 100 psi are approximately the same for the different crudes, the controlling term in equation (4) is k_o/k, which is determined by the residual oil or gas saturation.

It is to be emphasized that the above results are not to be used in estimating the recovery or determining the quantitative performance history of any particular gas drive reservoir. They have significance only with respect to the relative behavior of reservoirs having comparable rock characteristics and general structural features. It will be recalled that the calculations were all based on the assumption that the reservoirs are produced entirely by gas drive, without the aid of gravity drainage or water encroachment. Moreover, they have all been assumed to have a permeability-saturation relationship as given in Fig. 9, and that the connate water saturation was in all cases 25 per cent. In view of these assumptions, an application of the data reported here to any specific reservoir would be entirely unwarranted, except, as by mere coincidence, the reservoir fluid and rock characteristics, for the reservoir of interest happen to be substantially the same as those assumed here.

Acknowledgment is hereby made to Dr. P. D. Foote, executive vice president of the Gulf Research and Development Company, for permission to publish this material.

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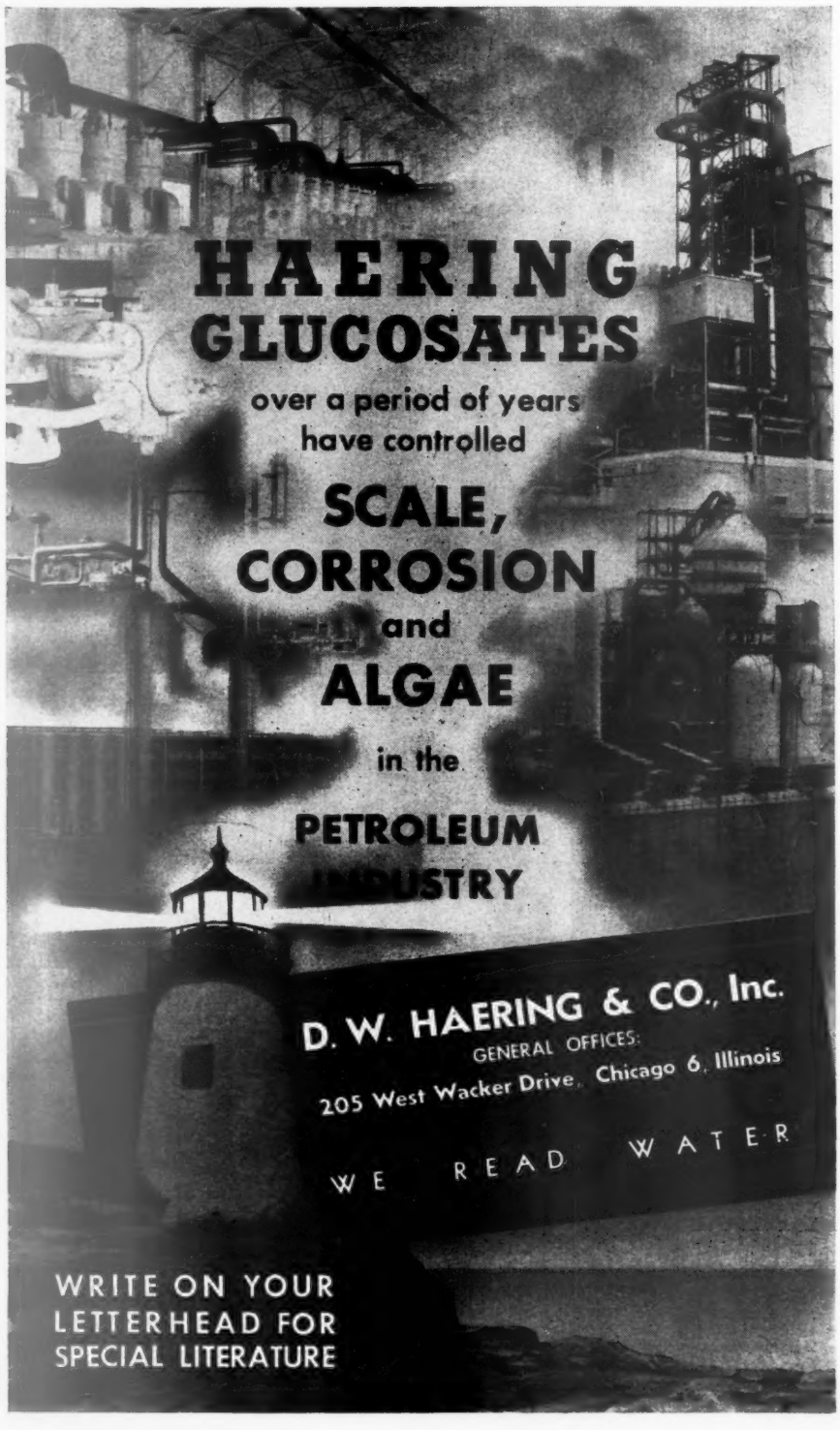

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Core analysis—

*Practical application to oil and gas reservoirs**

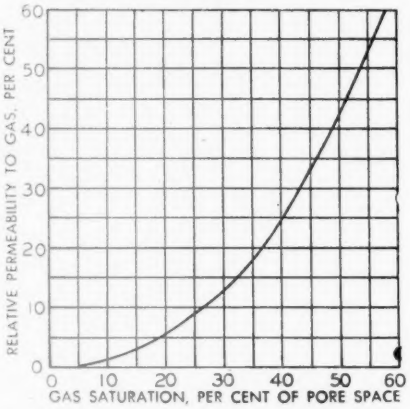
By **J. H. CAMPBELL,** Core Laboratories, Inc.

STANDARD core analysis procedures include determinations for porosity, permeability, residual oil and total water-saturation, and relative permeability to gas measurements. Connate water saturation is calculated from measured porosity and liquid saturation data. Other measurements, such as salinity of pore water, gravity of residual oil, grain size distribution, etc., are usually reported as supplemental information to assist in correct interpretations for probable production and application of the basic measured data to well completion and performance.

Porosity is a measure of the storage capacity of the sand. It is the ratio of pore volume to bulk volume of the rock. Porosity expressed as a fraction can be converted to barrels per acre-foot by multiplying the porosity fraction by 7758 (total barrels per acre-foot).

Permeability is a measure of the flow of fluid through a porous medium. Darcy's Law governing flow of fluid through solids is the basic equation underlying laboratory determinations of permeability of reservoir rocks. The API Standard Code No. 27 presents the formula for calculating permeability as well as laboratory procedures and techniques and certain specifications for purposes of reporting uniform and accurate permeability values.

FIG. 1
Relative permeability to gas.



Formation name: Raleigh. Depth, feet: 7017-7037. Number of samples included in relative permeability averages: 3.

Gas saturation, %	Relative Permeability, % (1)
3	0
6	0.4
9	1.1
12	2.0
16	3.6
20	5.6
25	8.9
30	12.8
35	17.8
40	24.8
45	33.1
50	42.9

(1) Average relative permeability to gas, per cent of permeability at 100 per cent gas saturation.

Oil saturation measured in cores at surface conditions ordinarily is interpreted to be residual oil saturation after the formation has been subjected to complete flushing by water invasion and expansion of released gas that was originally in solution with the residual oil. When the drilling fluid is oil or oil base mud, residual oil saturation then approaches that value which may be expected when the formation has been depleted by dissolved gas drive only. The magnitude of residual oil saturation is indicative of the efficiency of recovery by gas expansion production vs. water drive production. Oil saturations in the order 10-25 per cent pore space usually are measured when water base muds are used as compared to 40-80 per cent of pore space when oil base muds are used.

Connate water is the water saturation inherent to the formation. Connate water may be determined as a direct measurement by core analysis in shallow fields when cores are taken in an oil or oil base coring fluid medium. This does not follow in deep horizons where high reservoir temperatures are encountered. Connate water is calculated when water base muds are used since core analysis gives a measure of total water saturation in this coring procedure. This calculation is based on an empirical equation involving measurements of gas and liquid saturation of cores at surface conditions. Satisfactory checks for calculated connate water saturation have been made in the same horizon in the same field by quantitatively measuring in cores the amount of an infiltrated tracer, and from the results of water saturation measurements in cores taken in oil or oil base muds. Fluid Index (Core Laboratories, Inc.) is an interpretive index based directly on calculated connate water saturation to show probable expected production from a given horizon.

Core analysis measurements as described above can be successfully applied to well and reservoir performance; first, as a means of interpreting the type and amount of fluid that will be produced from the cored interval, and second, by providing the basic data from which it is possible to calculate oil recovery by primary or secondary methods of production.

The type of production (gas, oil, or water) can be predicted from the results of fluid saturation determinations; that is, degree of residual oil saturation and connate water saturation, permeability being sufficient for a favorable rate of flow.

The amount of oil production can be calculated by means of the productivity index equation. This equation is written as follows[1]:

$$I = \frac{5.9 \times 10^{-4} \times K \times T}{u \times F.V.F.}$$

I = productivity index, bbl. of oil per day per lb. pressure differential,
K = average permeability of exposed thickness, millidarcys,
T = thickness of exposed productive interval, ft.,
U = viscosity of oil at reservoir temperature and pressure, centipoises,
F.V.F. = formation volume factor of reservoir oil-volume occupied at saturated reservoir conditions by unit volume of stock-tank oil.

The productivity index equation may be further refined by introducing a factor for the relative permeability characteristics of the formation at the existing gas saturation in the horizon.

The volume of gas production from a gas phase reservoir can be calculated from the following equation:

$$Q = 1.075 \times 10^{-3} \times K \times T \ (P_1^2 - P_2^2)$$

Q = volume gas, cu. ft. in 24 hr.,
K = permeability, millidarcys,
T = thickness of exposed productive interval, ft.,
P_1 = shut-in pressure, lb. per sq. in. abs., and
P_2 = flowing pressure, lb. per sq in. abs.

This equation is applicable to gas phase reservoirs where there has been no appreciable liquid saturation created in the formation by the process of retrograde condensation. Conversely, it cannot be used rigorously to calculate gas injection volumes into reservoirs containing residual oil because relative permeability characteristics of the reservoir rock change with variation in reservoir fluid saturation conditions.

*Presented before Dallas Petroleum Engineer's Club, October 11, 1946.

[1]Lewis, Horner, Stekoll, "Productivity Index and Measurable Reservoir Charactertistics," *A.I.M.E. Tech. paper No. 1487*, October, 1941.

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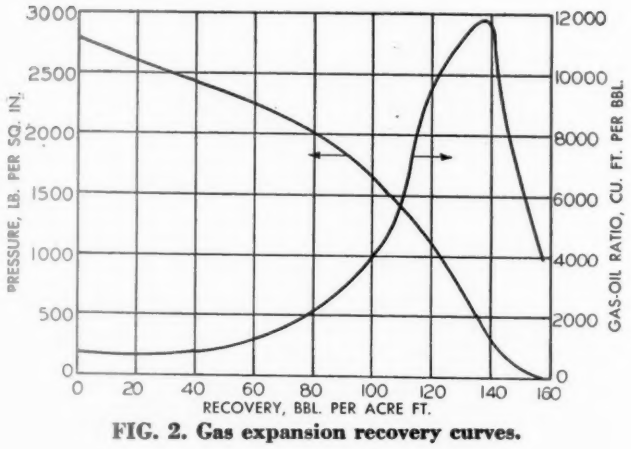
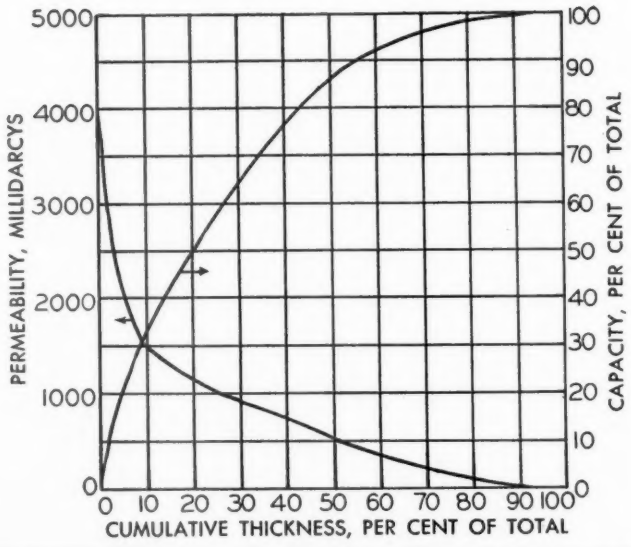


FIG. 2. Gas expansion recovery curves.



Formation name: Raleigh. Depth, feet: 7017-7037. Feet of formation recovered: 19. Feet of permeable formation recovered: 19. Average permeability, millidarcys: 708. Capacity, millidarcy-feet (3): 13,452. Distribution index (4): 28.

(1) Cumulative per cent thickness in order of decreasing permeability.
(2) Cumulative per cent of total capacity.
(3) Capacity of recovered formation only.
(4) Distribution index legend:
80-100 Excellent uniformity of permeability.
60- 80 Good uniformity of permeability.
40- 60 Fair uniformity of permeability.
20- 40 Poor uniformity of permeability.
0- 20 Very irregular permeability.

Thickness, % (1)	Permeability, Md.	Capacity, % (2)
1	3300	5.5
5	2090	21.1
10	1500	33.0
15	1280	41.8
20	1140	50.0
25	1020	57.3
30	920	64.2
40	730	76.6
50	540	86.2
60	350	92.2
70	210	96.0
80	105	98.2
90	45	99.3
100	0	100

FIG. 3. Permeability and capacity distribution.

Core analysis provides basic data for recoverable oil calculations by gas expansion and water drive methods of recovery. Gas expansion recovery is that obtained by release of dissolved gas in solution with oil, driving oil to the well bore. Gas expansion recovery usually is calculated with reservoir pressure decline from original reservoir conditions to zero pounds.

Reference has been made repeatedly to reservoir oil properties at conditions of reservoir pressure and temperature. Measured reservoir fluid data are essential to and used in conjunction with core analysis data to obtain accurate recoverable oil figures. Detailed recovery calculations and produced gas-oil ratio history are obtainable when the relative permeability characteristics of the producing formation are known (Fig. 1).

Relative permeability of a porous medium to a given fluid is defined as the ratio of the effective permeability to that fluid when the pores are partially saturated with the fluid, to the (specific) permeability when the pores are fully saturated. Relative permeability to a liquid declines rapidly with increasing gas saturation because the gas occupies the centers of the pores, thus blocking liquid flow through the larger channels. Relative permeability to gas is generally negligible at gas saturations of less than 5 per cent and small at gas saturations of from 5 to 10 per cent, for at these saturations the gas exists in the form of discrete bubbles rather than in a connected network. With increasing gas saturation the ratio of the relative permeability to gas to the relative permeability to oil increases rapidly. This ratio governs the rate of increase of free gas production and hence the rate of pressure decline in a reservoir produced by gas expansion.

Gas expansion recovery and gas-oil ratio history may be calculated from the material balance equation as a function of pressure, when the equation has been reduced to exclude the terms for gas cap, water encroachment, and gas injection. From core analysis, reservoir fluid analysis, and relative permeability data, such pressure decline and gas-oil ratio vs. recovery curves as given in Fig. 2 can be calculated.

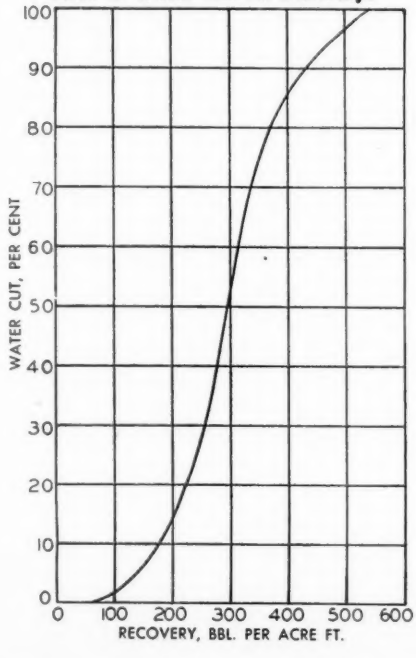
Water drive recovery includes recoverable oil obtained by water encroachment into the reservoir under conditions of a water influx rate of sufficient magnitude to maintain reservoir pressure at a high value (at or near original saturation pressure of the reservoir oil). In this method of calculation, core analysis data supplies necessary formation characteristics to supply unit water-drive yield. From the following equation, water drive recovery calculations can be made:

$$Wdr = \frac{(100 - S_{cw} - R_o) \times \Phi}{F.V.F.}$$

Wdr = water drive recovery, bbl. stock tank oil per acre-ft.,
S_{cw} = connate water saturation, per cent pore space,
R_o = residual oil saturation at reservoir conditions, per cent pore space,
F.V.F. = formation volume factor—volume that one bbl. of stock tank oil occupies in reservoir, and
Φ = porosity, bbl. per acre-ft. (fractional porosity × 7758).

The lateral flow of fluids in a formation of irregular permeability may be studied and the irregularities may be represented conveniently by a permeability distribution curve, Fig. 3. This curve graphically shows the arrangement of permeability, regardless of depth in a given formation, in order of decreasing permeability. The analysis is applied to reservoir performance when calculating recovery performance by water encroachment. It is a useful statistical approach to determine the productive capacity content for any given increment of total productive thickness. In general, the most permeable zones are first depleted, leaving the lower permeability zones to produce at a slower rate. The potential energy of the reservoir then begins to be wasted through the higher permeability channels. The more irreg-

FIG. 4. Water cut vs. recovery.



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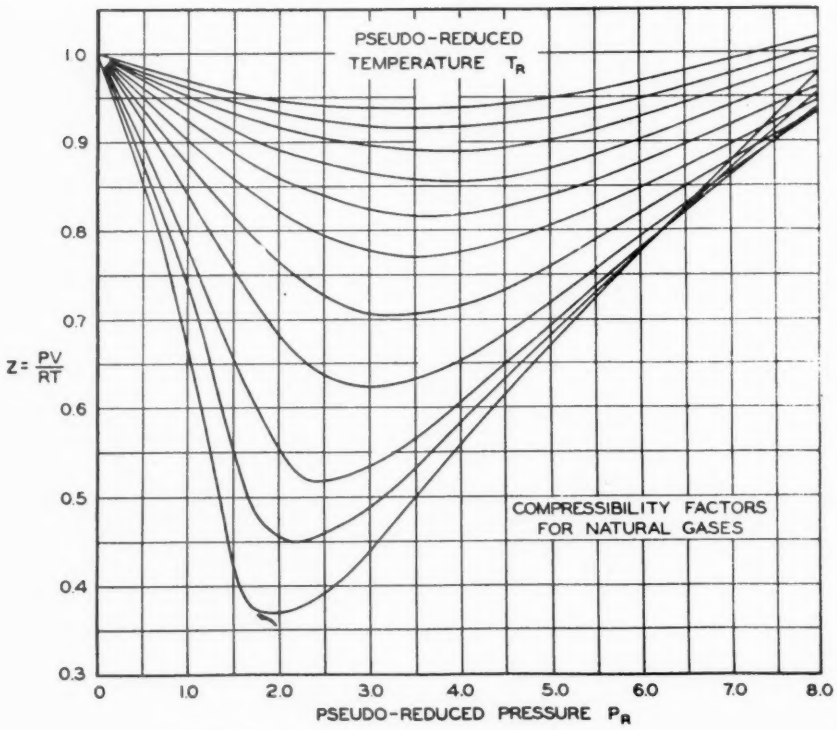

FIG. 5. Compressibility factors for natural gases.

ular the permeability, the greater will be the amount of residual oil in the tighter parts of the formation at the economic limit.

This analysis is supplementary to the final calculations for water cut-recovery study. Reservoir fluid properties and relative permeability of the formation to oil and relative permeability of the flushed formation to water are necessary data in addition to the permeability distribution analysis. The curve, Fig. 4, shows the calculated water cut for a given oil recovery. Further refinement of calculated performance can be gained with use of electrolytic model studies from which coverage and pattern effects may be obtained. These effects are correlated with permeability distribution of the formation, viscosity ratios of encroaching or injected fluid to reservoir fluid, to give proportionate areas affected by water encroachment.

Gas reserves may be determined with use of the following formula:

$$V_s = 1.541 \times 10^6 \frac{P_r}{Z_r T_r} \Phi (1 - S_{cw})$$

V_s = cu. ft. of gas at standard conditions per acre-ft. of reservoir formation,
P_r = reservoir pressure, lb per sq. in. abs.,
T_r = reservoir temperature, °Rankine (°F + 460),
Z_r = compressibility factor of gas,
Φ = fractional porosity, and
S_{cw} = fractional connate water saturation.

The ability to calculate gas reserves, once core analysis is obtained, depends primarily upon the ability to calculate Z. The chart applicable to calculating Z for natural gases is given in Fig. 5, which is obtained from George Granger Brown[2]. Z may be determined accurately, either from the gas composition or gas gravity.

Core analysis in pressure depleted formations supplies necessary information for complete evaluation of the horizon for purposes of secondary recovery. Applicability of the formation to gas injection or water injection, and expected recoveries and performance under either gas or water injection, are quantities determinable from the results of core analysis when properly applied and used.

★★★

[2]Brown, G. G., *N.G.A.A. Proceedings, 1940;* p. 54. *Petroleum Engineer* series, 1940.

Overwater oil well

A site in Pamlico Sound off the North Carolina shore has been selected for the first overwater drilling ever attempted along the Atlantic Coast, it is announced by M. J. Rathbone, president of Standard Oil Company (N. J.).

The well will be 17 miles from Manteo, North Carolina, and 32 miles north of historic Hatteras Light where the company recently plugged as a dry hole an exploratory well that reached a depth of 10,054 ft. The site is about three miles west of Barrier Beach, where the depth of the water is about five feet.

Interpretations of drilling results at Hatteras, coupled with data obtained from extensive seismograph surveys of the area, led to choice of Pamlico Sound site.

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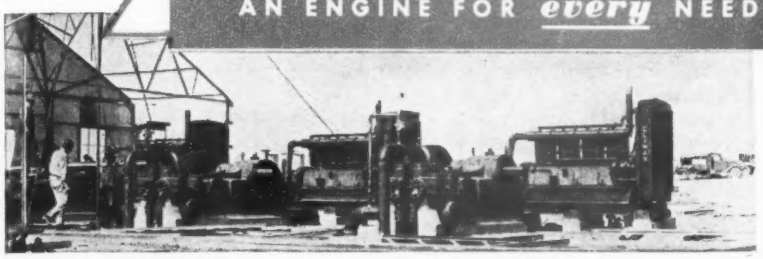

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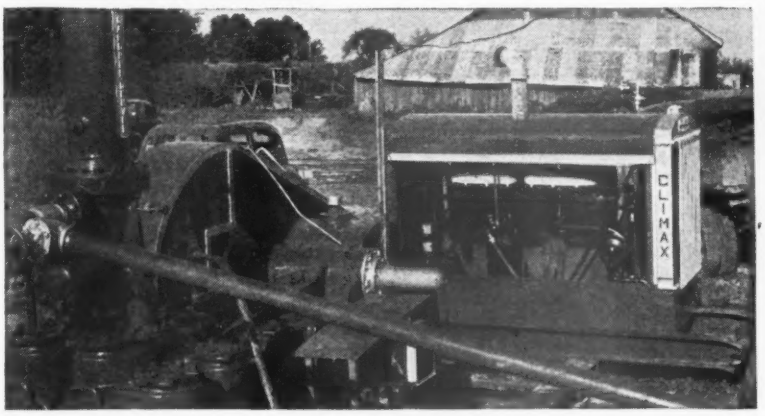

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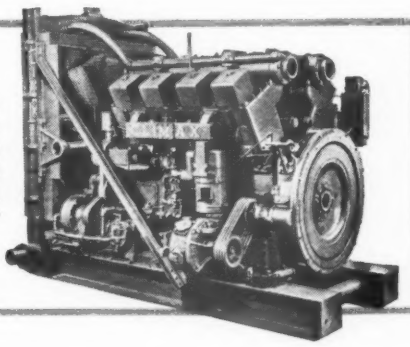

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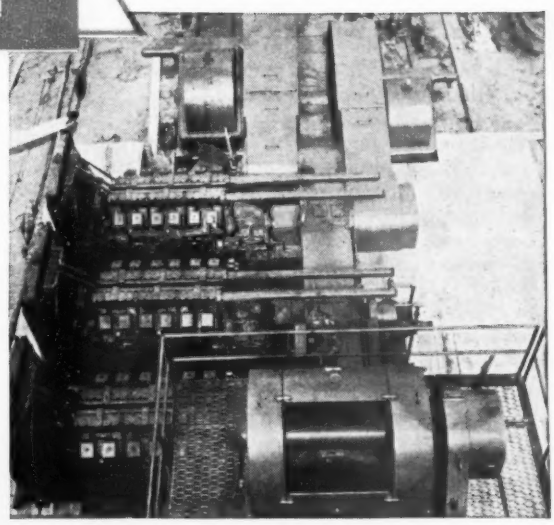

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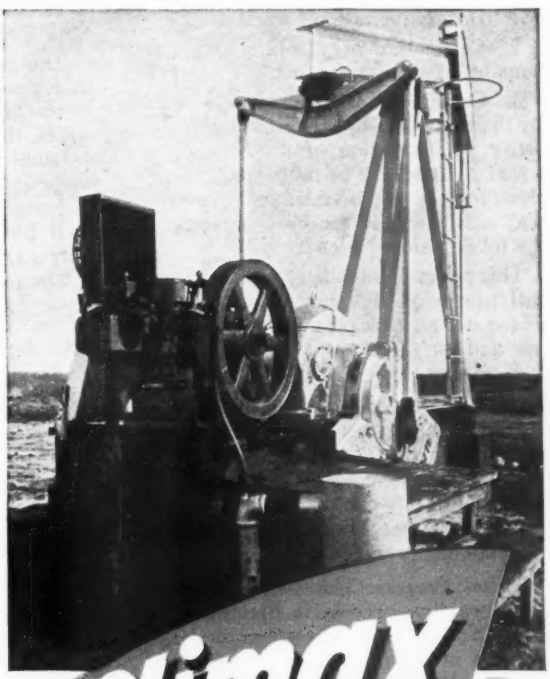

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Processes for octane improvement*

By **DAVIS READ,** Universal Oil Products Company

ALTHOUGH it is generally realized that the average automobile on the road today is not designed to appreciate better fuels than those now produced, it appears that future competition will continue to force motor fuel octane numbers upward. It is significant to note that the average octane numbers of the gasolines marketed in the eastern and Pacific Coast areas, which are supplied largely by refiners employing the recently developed catalytic processes, are somewhat higher than those marketed in the middle and southwestern sectons of the United States. If it is assumed that this trend will continue in the future, the problem of modernizing refineries in the Mid-Continent and southwestern areas to meet this competition assumes considerable importance.

The leaded octane ratings of the total gasoline produced from a barrel of crude oil can be improved by at least three well known methods, listed approximately in the order of increasing capital cost to the refiner:

1. Desulphurization of gasoline.
2. Conversion of gasoline hydrocarbons by reforming.
3. Conversion of hydrocarbons heavier than gasoline by cracking. Polymerization or alkylation of the gases produced by cracking or reforming may be classified as complementary processes that also increase the octane rating of the total gasoline blend.

This paper is intended to describe several processes that may be used to increase octane rating by the above methods and to discuss the application of each process.

● **Desulphurization of gasoline.** Mercaptan sulphur can be removed from straight run or cracked gasoline either by extraction or catalytic conversion to another sulphur compound, such as hydrogen sulphide, which may be easily eliminated.

Unisol Process. The Unisol mercaptan extraction process is illustrated in Fig. 1. This process is based on the large increase in solubility of mercaptans in caustic solution when an organic solvent, methyl alcohol, is present. The mercaptans are thus bodily removed instead of being converted to disulphides, which suppress lead susceptibility, as they are in the conventional doctor treating process. A substantial reduction in the sulphur content of the gasoline is thus obtained and is usually accompanied by a marked increase in lead susceptibility. Gasoline is washed free of hydrogen sulphide and aliphatic acids in a simple dilute caustic prewash. The prewashed feed is then contacted with a concentrated aqueous solution of caustic soda and methanol in a countercurrent extraction column. This extraction is carried out at about 100°F. under a pressure of 75-100 lb. per sq. in. The caustic solution is introduced at the top of the column and moves downward against the rising flow of gasoline.

Methanol is introduced at a point midway in the column. The caustic solution in the upper portion of the column above the methonal inlet selectively extracts methanol from the gasoline and thus prevents methanol loss. The portion of the column below the solvent inlet is the mercaptan extraction section.

The menthanol and mercaptans are removed from the caustic solution by heating and stripping in a separate column with steam. The recovered caustic is circulated back to the extraction column for re-use.

The methanol, mercaptans, and the steam used for stripping are condensed to produce a methanol-water mixture in which the mercaptans are substantially insoluble. The mercaptans separate and form an oil layer over the methanol solution and are removed from the process as a liquid. These mercaptans contain only a trace of gasoline.

The process is most effective on thermally cracked or reformed gasoline, which usually contains more mercaptan sulphur than the corresponding straight run gasoline. Table 1 shows typical commercial results obtained in Unisol treating of thermally cracked gasoline. As this Mid-Continent cracked gasoline was low in both mercaptan and total sulphur content, only a slight improvement in lead response was obtained by extracting the mercaptans completely. On the other hand, West Texas thermally cracked gasoline containing about 0.3 per cent mercaptan sulphur showed an increase of nearly three units in the leaded octane number after Unisol treatment. The degree of improvement, therefore, depends upon the concentration and type of the mercaptans in the raw gasoline.

Gray catalytic desulphurization. This process removes sulphur compounds from the gasoline by catalytic conversion to hydrogen sulphide, which is stabilized out as indicated on Fig. 2. It is used principally to process straight run gasolines because (1) the types of sulphur compounds in the straight run are susceptible to this method, and (2) when cracked gasoline is treated the catalyst life is rather short. Raw gasoline, which need not be stabilized, is preheated and introduced into clay towers arranged for alternate operation to permit replacement of the clay. The product from the clay towers is partially cooled by heat exchangers and introduced to a fractionating column. The overhead from this column is condensed and passed to a

FIG. 1. The Unisol process.

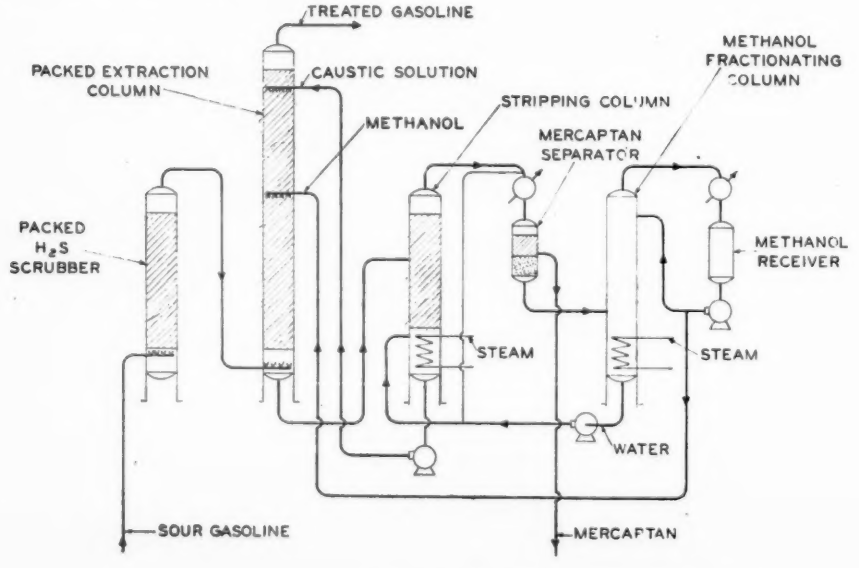

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TABLE 1

Unisol treating — commercial results.

Stock	Mid-Continent 400°F. EP thermally cracked		West Texas 400°F. EP thermally cracked	
Treatment	None	Unisol	None	Unisol
Mecaptan sulphur, per cent	0.014	None	0.27	0.004
Total sulphur, per cent.	0.06	0.05	0.53	0.26
Octane numbers				
Motor Method clear..	68.7	68.7	69.5	70.6
+3 cc. TEL per gal..	77.8	78.4	73.7	76.6

receiver from which the gaseous products from the reaction, principally hydrogen sulphide, are separated. The liquid from the receiver is stabilized to adjust vapor pressure and remove residual hydrogen sulphide. The liquid products are ordinarily caustic washed to insure freedom from traces of hydrogen sulphide.

Table 2 shows the results obtained by desulphurizing Mid-Continent and West Texas straight run gasolines. The low sulphur Mid-Continent gasoline showed an improvement of about 1.5 points in the leaded octane rating by this process. The high sulphur West Texas stock was reduced to 0.06 per cent total sulphur with only a trace of mercaptan left and the leaded octane rating increased from 63.3 to 75.1. Thus, the degree of octane improvement obtained by catalytic desulphurization depends upon the amount and type of sulphur compounds present in the raw straight run, which depress its lead susceptibility.

From the preceding discussion it appears that some octane improvement can be realized by the removal of the sulphur from Mid-Continent straight run or thermally cracked and reformed gasolines, but in general the effect is small when the sulphur content is low. Many Mid-Continent gasolines of course contain more sulphur than the gasoline used for illustration and as a result a correspondingly greater octane improvement is obtained by desulphurization. The next alternative for improving the quality of gasoline from low sulphur Mid-Continent crude is to convert the gasoline hydrocarbons into compounds of higher octane number.

● **Conversion of gasoline hydrocarbons by reforming.** Thermal reforming is the conventional process used for improving the octane rating of straight run fractions. At the present time a considerable amount of research work is being done on the catalytic conversion of hydrocarbons normally boiling in the gasoline range. In most cases the octane improvement obtained is a result of both desulphurization and a change in the structure of the hydrocarbons. Thermal reforming plus catalytic polymerization of the gases produced is the yardstick by which most of these catalytic reforming processes are evaluated. In order to be attractive the catalytic process must produce an octane number considerably better than the thermal reforming and polymerization operations, for which some refiners are presently equipped.

Isoforming. The isoforming process is designed to increase the octane rating of cracked gasoline by isomerization of the olefins. It is a fixed bed catalytic process that operates at a temperature of 750-1000°F. at a relatively low pressure of 5-20 lb. per sq. in. and requires regeneration of the catalyst.

Table 3 shows pilot plant results obtained in isoforming a 68-octane number thermally cracked gasoline to produce a yield of 98.5 per cent of gasoline having an octane of 81.0 with 3.0 cc TEL per gal. This yield octane relationship appears to be somewhat better than the results obtainable by prefractionation of the cracked gasoline, thermally reforming the cracked naphtha and reblending.

Uniforming. The uniforming operation improves the octane rating of the straight run and thermally cracked fractions catalytically, but it is still in the laboratory and pilot plant stage of development. This operation is conducted at relatively high pressure in the range of 500-1000 lb. per sq. in. and at a temperature of 900-1000°F. in the presence of recirculated hydrogen. The high concentration of hydrogen in the reactor suppresses the formation of carbon so that the catalyst remains relatively clean after long periods of use. To be self-supporting, the operation is carried out at processing conditions that will yield a small net make of hydrogen.

Table 4 shows the pilot plant results

TABLE 2

Gray catalytic desulphurization.

Stock	Mid-Continent 385°F. EP straight run		West Texas 400°F. EP straight run	
Treatment	None	Clay 700°F. 0 lb. per sq. in. 1.0 S.V.	None	Clay 700°F. 20 lb. per sq. in. 1.0 S.V.
Total sulphur, per cent	0.03	0.01	0.35	0.06
Mercaptan sulphur, per cent	0.004	None	0.14	Trace
Octane numbers				
Motor Method clear.	52.5	53.0	51.5	58.0
+3 cc. TEL per gal..	73.5	74.9	63.3	75.1

TABLE 3

Isoforming—pilot plant results.

Stock	Mid-Continent 400°F. EP thermally cracked	
Treatment	None	Isoformed
Yield, vol. per cent of charge	100.0	98.5
Octane numbers		
Motor Method clear	68.1	73.4
+3 cc. TEL per gal	76.6	81.0
Reid vapor pressure, lb	9.9	10.0
Mercaptan sulphur, per cent	0.011	None
Total sulphur, per cent	0.05	0.04
End Point, °F	403	440

TABLE 4

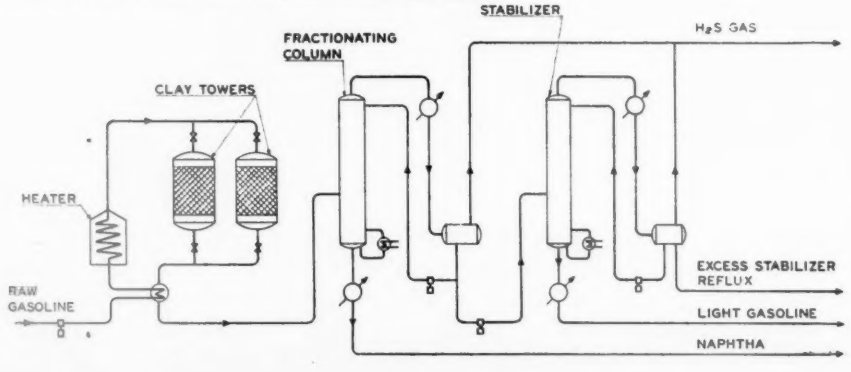
Uniforming—laboratory and pilot plant results.

Stock	Kansas		Illinois straight run	
Treatment	None	Uniformed	None	Uniformed
Yield, vol. per cent of charge	100.0	88.0	100.0	79.9
Octane numbers				
Motor Method clear.	39.2	61.6	50.4	63.6
+3 cc. TEL per gal..	61.3	80.4	69.9	80.3
Reid vapor pressure, lb.	1.9	6.4	5.5	3.5
Mercaptan sulphur, per cent	..	None	0.02	None
Total sulphur, per cent.	0.03	0.01	0.03	0.01
End point, °F.	384	387	400	402

obtained on both a Kansas and an Illinois straight run gasoline. These results are better than it is possible to obtain by thermal reforming followed by polymerization, but the application of the uniforming process appears to be limited to certain types of stocks. Some gasolines are much more susceptible to uniforming than others that have essentially the same boiling range and initial octane number. The exact reason for this has not been determined and further laboratory research on other catalysts is being conducted.

● **Conversion of hydrocarbons heavier than gasoline by cracking.** Comparisons of thermal and catalytic cracking of heavier stocks show an advantage of 8-10 units in the octane rating of the gasoline produced from catalytic cracking, with little difference in the installation and operating costs for the two processes. However, the installation costs per barrel of gasoline produced are higher for either thermal or catalytic cracking than for any of the processes previously discussed.

FIG. 2. Gray catalytic desulphurization process.



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Fluid catalytic cracking. The fluid catalytic cracking process employs the principle of contacting the oil vapors with catalyst in a finely divided state so that the mixture of catalyst particles and oil vapors acts as an intimately mixed fluid. This process is illustrated by the flow diagram shown on Fig. 3. The oil feed, which may be kerosine, gas oil, or some types of topped crude, is charged as a liquid at the base of the reactor riser. The hot regenerated catalyst flows through a slide valve into this riser, vaporizes the raw oil, and is transported upward by the oil vapors into the reactor in much the same manner as large particles of dust might be carried in suspension in a stream of air. The hydrocarbons are cracked in the reactor, which operates at 800-1000°F. and at a pressure of 9-10 lb. per sq. in. ga. The reaction products then pass as a vapor to the fractionator where gasoline and gas are separated from the fractions boiling above 400°F. These fractions may be recycled to the reactor to increase the gasoline yield at the expense of fuel oil.

During the cracking reaction about ½ to 1 per cent coke is deposited on the catalyst, which is subsequently removed by combustion with air in the regenerator. The heat released in regeneration is utilized to vaporize the raw oil by direct contact with the hot catalyst in the riser, as previously mentioned. The spent catalyst containing the coke overflows the top of the internal stripper and passes down through the external stripper and slide valve and enters the regenerator. Steam is injected into both the internal and external strippers to remove entrained hydrocarbon vapors that would otherwise be lost by burning in the regenerator. The regenerator operates at an average temperature of about 1050°F. and at 15-18 lb. pressure. The temperature in the top of the burning zone is about 950°F., while the bottom zone operates at 1100-1150°F. This temperature gradient from the top to the bottom of the regenerator is caused by the presence of grid plates in the catalyst bed, which improve the distribution of catalyst and air and permit more complete utilization of the oxygen than was possible in the fluid units operated during the war. The addition of grid plates in both the reactor and stripper also improves the distribution of catalyst in these zones and increases the efficiency of these operations. The hot regenerated catalyst flows from the bottom of the regenerator to the reactor riser to complete the catalyst circuit.

The air stream enters the bottom of the regenerator and passes countercurrent to the flow of catalyst and the products of combustion pass from the top of the

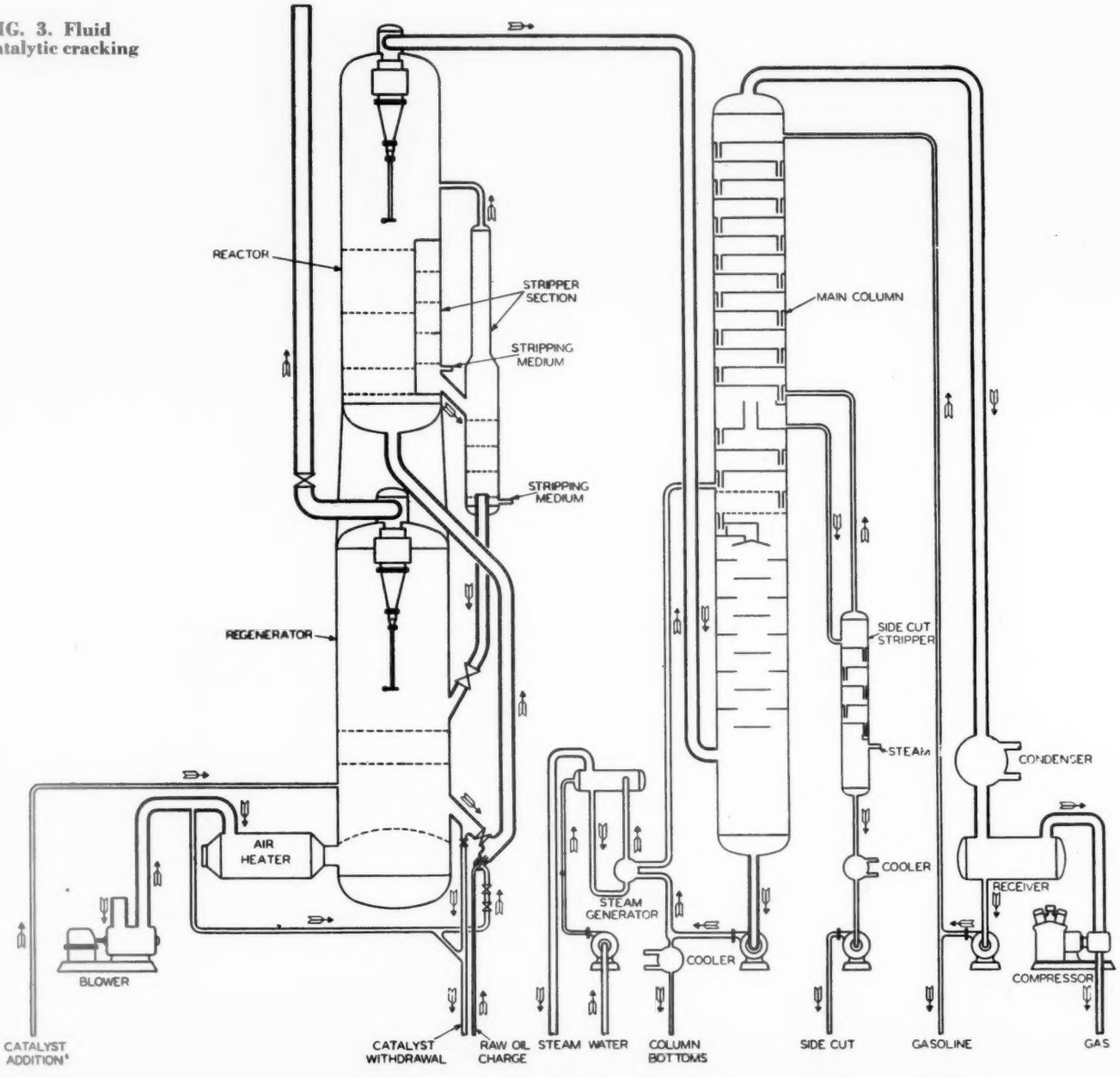

FIG. 3. Fluid catalytic cracking

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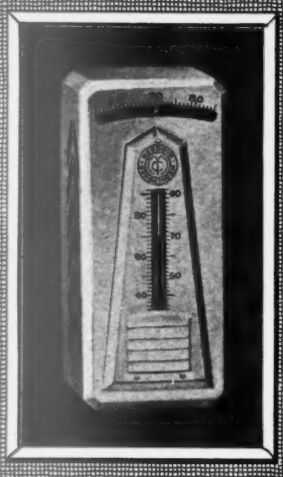

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TABLE 5
Fluid catalytic cracking, 31-deg. API Mid-Continent gas oil, silica-magnesia catalyst, pilot plant results.

Operation	Once-through	Recycle	
Conversion, per cent	65	65	80
Yields, vol. per cent			
Debutanized gasoline	53.0	56.0	62.0
Cycle oil	35.0	35.0	20.0
Butylenes	5.5	5.3	7.1
Butanes	5.5	3.2	5.1
Propylene	3.8	3.6	5.1
Propane	1.9	1.7	2.7
C_2 and lighter gas, wt. per cent.	1.9	1.8	2.9
10-lb. R.V.P. catalytic gasoline	55.9	59.0	65.2
10-lb. R.V.P. polymer gasoline	6.0	5.9	8.1
Total 10-lb. R.V.P. gasoline	61.9	64.9	73.3
Octane Numbers of 10-lb. catalytic gasoline			
Motor Method clear (F-2)	79.8	78.2	79.2
+3 cc. TEL per gal	86.7	85.0	85.5
Research Method Clear (F-1)	89.7	89.7	91.2
+3 cc. TEL per gal	96.3	96.3	97.4

TABLE 6
Breakup of Mid-Continent crude oil.

Crude distillation yields, vol. per cent	
Crude charge (30-deg. API gravity)	100.0
Straight run	22.0
Kerosine	10.0
Distillate fuels	19.0
Reduced crude (25.5-deg. API gravity)	48.0
Loss	1.0
Properties of straight run gasoline	
Octane numbers	
Motor Method clear	51.0
+3 cc. TEL per gal	72.5
Reid vapor pressure	9.5
Total sulphur, per cent	0.03
Mercaptan sulphur, per cent	0.01

regenerator to the atmosphere through internally mounted cyclone separators which recover entrained catalyst.

Thus it is seen that there are three principal flowing streams in the fluid process:

(1) The oil passes through the reactor to the fractionator.
(2) Air for regeneration of catalyst passes once through the regenerator.
(3) The catalyst itself circulates with the system.

Table 5 shows the yields obtained in pilot plant once-through and recycle cracking of 31°API Mid-Continent gas oil over silica magnesia catalyst. A comparison of the first two columns of the table shows that the debutanized gasoline yield can be increased from 53-56 per cent, at the expense of gas production, by recycling at a constant conversion of 65 per cent. This operation may be carried out by reducing a part of the unconverted gas oil to the reaction zone. The decreased conversion per pass resulting from recycling in this case reduced the Motor Method octane number. The last column of the table shows the yields that were obtained when the conversion was increased to 80 per cent by recycling and increasing the amount of catalyst in the reaction zone. In this case the total 10 lb. RVP gasoline yield, including polymer, amounts to about 73 per cent of the gas oil charged and the Motor Method leaded octane number of the catalytic gasoline was 85.5.

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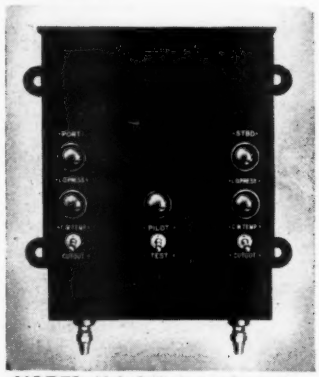

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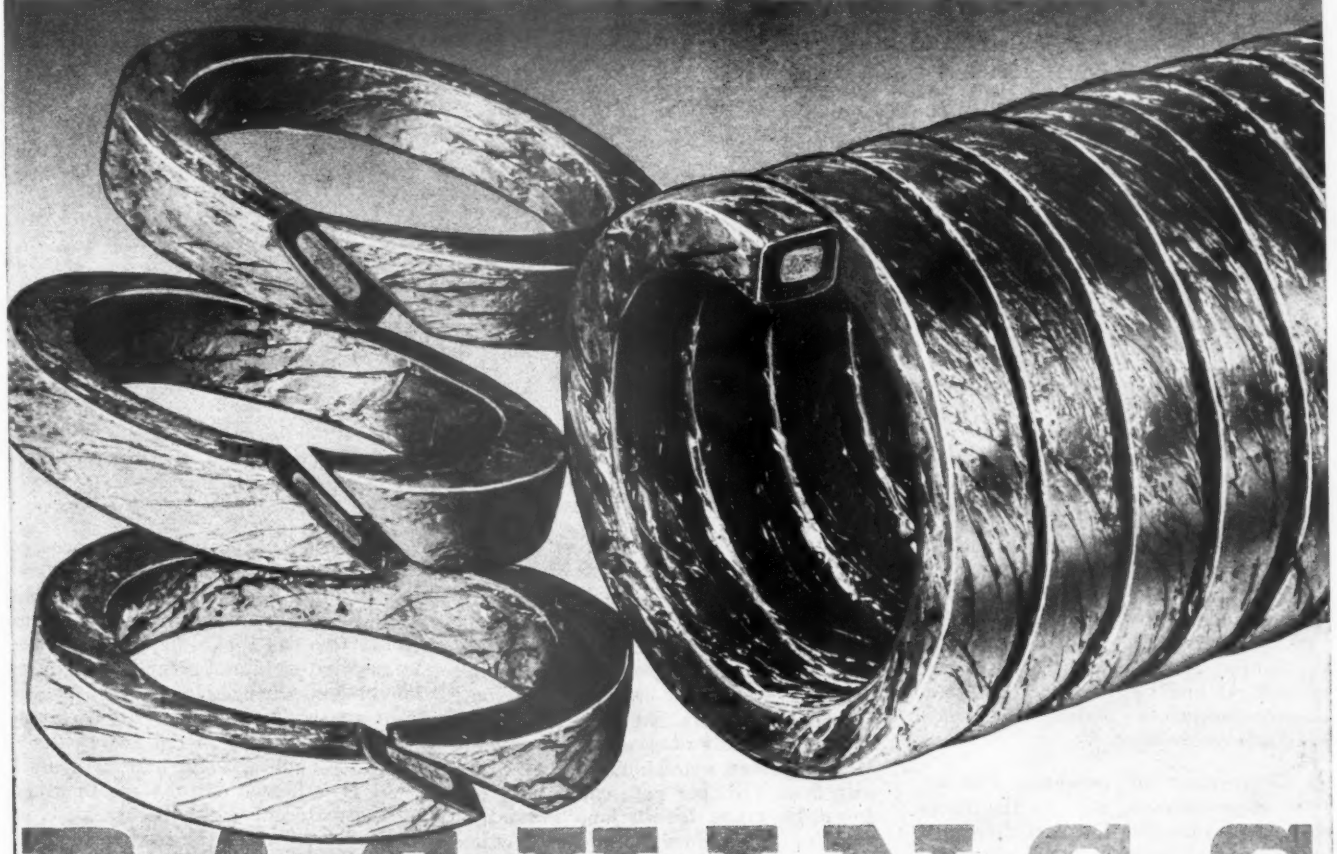

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TABLE 7—Comparison of processes added for octane improvement.

	Conversion of gasoline hydrocarbons					Conversion of hydrocarbons heavier than gasoline	
	A	B	C	D	E	F	G
	Crude distillation, thermal cracking, polymerization, copper sweetening and Unisol treating	Plus thermal reforming straight run gasoline	Plus uniforming straight run gasoline	Plus isoforming thermal cracked gasoline	Plus thermal reforming straight run and isoforming thermal cracked gasoline	Plus vacuum unit and catalytic cracking of gas oil†	Replace thermal cracking reduced crude with catalytic cracking gas oil‡
Estimated yields—vol. per cent of crude							
Copper sweetened straight run	22.0			22.0		22.0	22.0
Thermally reformed straight run		17.6			17.6		
Uniformed straight run			19.3				
Unisol treated 400° FEP thermally cracked	24.5	24.7*	24.5			8.0	
Isoformed 400° FEP thermally cracked				24.1	24.3*		
400° FEP catalytic cracked						25.9	25.9
Polymer	1.9	3.4	1.9	1.9	3.4	5.0	4.5
Total 10-lb. R.V.P. gasoline	48.4	45.7	45.7	48.0	45.3	60.9	52.5
Kerosine	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Distillate fuels	19.0	19.0	19.0	19.0	19.0	10.0	17.3
No. 6 fuel	19.2	19.6	19.2	19.2	19.6	11.3	15.4
Estimated MM. octane no. of total gasoline blend+ 3 cc. TEL per gal.	77.3	79.5	81.0	78.7	81.2	80.5	82.7

*Includes gasoline from thermally cracking reformer residue.
†The feed to the catalytic cracking unit consists of 40 per cent vacuum gas oil and 9.0 light gas oil based on crude. The vacuum unit bottoms and catalytic cycle stock are thermally cracked.
‡Same operation as that shown in Scheme F without thermal cracking of catalytic cycle stock or vacuum unit bottoms.

types of catalyst that give somewhat different results: A synthetic catalyst composed of silica alumina gives a higher octane number but a lower gasoline yield than the silica magnesia catalyst; the natural Filtrol catalyst gives a gasoline yield and octane rating intermediate to the values obtained by the two synthetic catalysts.

● **Comparison of processes for octane improvement.** Due to the large number of variables involved there are many ways of comparing the processes that have been discussed. The type of crude to be refined and yield and quality of products other than gasoline that are to be produced will, of course, affect the application of each process for octane improvement. One method of comparison is to consider the overall yields and leaded octane number of the total gasoline obtainable from a specific crude oil by the various refining schemes. The disposal of straight run naphtha as special solvents, will, of course, affect the gasoline yield-octane relationship, but if it is assumed that solvents are not produced in any of the cases, the overall results of the study should be on a comparable basis. This comparison has been made on the basis of the Mid-Continent crude breakup given in Table 6 and the results are shown in Table 7.

It should be pointed out that the numbers in these tables are estimates of the yields and octane blending values that could be obtained, based on the correlations of laboratory and pilot plant work on many different crude oils. Experimental tests have not been made to compare all the processes on the same sample of Mid-Continent crude. It is believed, however, that Table 7 shows a reasonably accurate estimate of the results obtainable in small scale equipment with present catalysts and technique. The development of new catalysts for the uniforming, isoforming, or catalytic cracking processes may well alter this comparison.

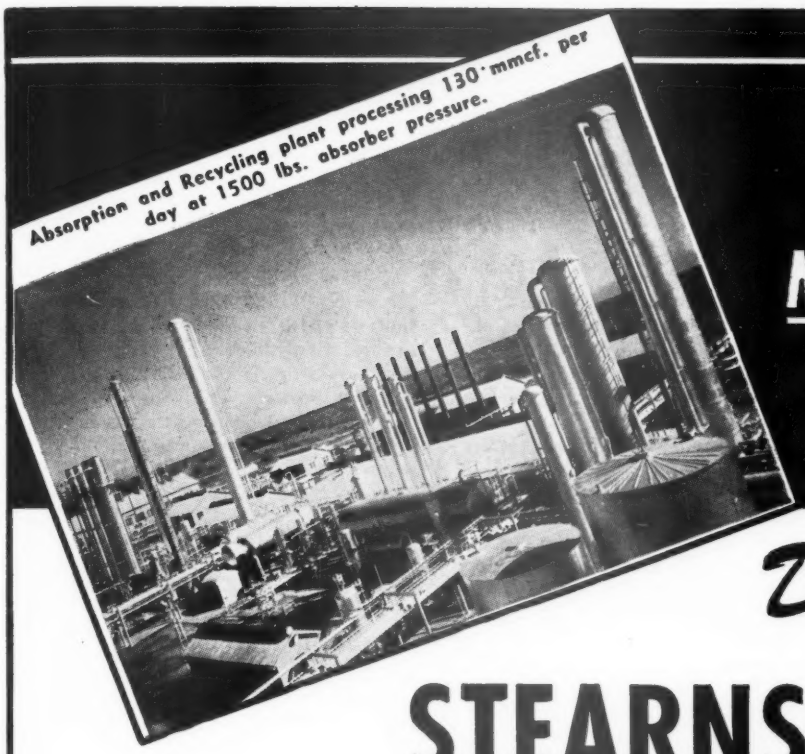
Starting with the 39° API gravity crude as the raw material, and assuming that no casinghead gasoline or outside blending agents are available, Column A of Table 7 shows that an overall yield of 48.4 per cent of gasoline, having a Motor Method octane number of 77.3 with 3 cc TEL per gal., could be produced by crude distillation, thermally cracking the reduced crude, catalytic polymerization of the gases from cracking, copper sweetening the straight run gasoline, and Unisol sweetening the thermally cracked gasoline. Dut to the low sulphur content of the straight run gasoline it is probably more economical to copper sweeten this stream than to desulphurize it by other methods. Note that 10 per cent kerosine, 19 per cent of straight run distillate fuels, and 19.2 per cent of cracked No. 6 fuel oil are also produced in this scheme. It should be noted that a higher overall gasoline yield could be obtained by thermally cracking distillate fuel as well as the reduced crude but there would be little change in the overall octane number of the total gasoline produced. Considering this operation as the basic case, and that the thermal cracking capacity is fixed, comparison of the various processes that might be added to this refining scheme to improve the octane number are given in Columns B-G of Table 7.

Of the processes added to convert gasoline hydrocarbons, either uniforming the straight run gasoline (Column C) or the combination of thermally reforming the straight run and isoforming the thermally cracked gasoline (Column E) show the best results. As indicated in Column D isoforming the cracked gasoline alone produced the lowest overall octane improvement.

As would be expected, these processes that increase octane number by converting gasoline already produced, do so at the expense of the overall gasoline yield; whereas a considerable increase in gasoline yield and octane rating may be obtained when the cracking capacity is increased by adding fluid catalytic cracking as shown in the last two columns of Table 7. The highest overall yield is indicated for the combination of thermal and catalytic cracking in Column F in which the feed to the catalytic unit consists of 40 per cent heavy gas oil (based on crude) from the vacuum unit and 9 per cent light gas oil from the crude unit. The vacuum unit bottoms and catalytic cycle stock are thermally cracked. The straight run distillate fuel and cracked fuel oil yields are thus reduced to 10.0 and 11.3 per cent, respectively, in this operation. The highest overall octane number is obtained when catalytic cracking replaces thermal cracking, as shown in Column G.

As previously mentioned, there are many other bases upon which these processes may be compared, such as maximum gasoline yield obtainable at a given octane level, or the lead requirement for a given octane number at a given yield. In any case it appears from this study that the maximum octane number improvement can be obtained by the addition of catalytic cracking.

If it is believed that only a slight increase in motor gasoline octane numbers should be expected in the future such processes as uniforming and isoforming, which convert gasoline hydrocarbons, may be advantageous. If on the other hand it is necessary to produce 80-octane regular and 85-octane premium gasoline, these gasoline conversion processes must be considered at the present time only as stop gap measures when applied to the refining of low sulphur Mid-Continent crude oil. ★★★



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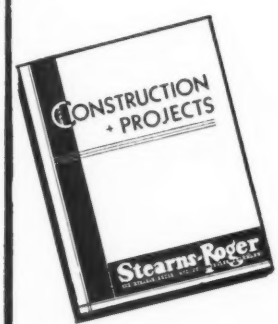

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Chemical resolution of oil-in-water emulsions

By **LOUIS T. MONSON**

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EXCLUSIVE

When reference is made to petroleum emulsions, one almost automatically thinks of emulsions of the water-in-oil type, the ordinary "cut oil" of the petroleum producing industry. That problem has existed so long and has caused so many headaches that producers have learned to handle such emulsified oil and recover the oil content thereof. Cut oil, bottoms settlings, "B.S.", or whatever it may be termed, comprises small water droplets dispersed or distributed throughout a volume of crude oil. The particles are commonly of different sizes, and are stably dispersed, i.e., there are enveloping films of emulsifying agent on the surfaces of the drops that prevent their coalescence.

Such emulsions are usually quite stable as to both time and temperature. Consequently it is usually found necessary to apply something more than simple standing or heating to reasonable levels in order to resolve them and to recover clean, dry, salable oil. Such emulsions may be resolved or broken chemically, using specific members of a large number of special chemical reagents, or by electrical methods, or by other means. Oil-treating procedures are and long have been routine in the business of producing crude oil. Some phases of the problem of handling and testing crude oil emulsions of the water-in-oil type have been considered in two earlier companion articles.*

Another but less well-known emulsion problem has confronted the oil producers in a few areas for many years. Certain California fields, especially in the vicinity of Bakersfield and at the east side of the Los Angeles Basin, have been producing oil-in-water emulsions in addition to wet oil or clean oil plus free water. Fort Collins, Colorado, and Duval County, Texas, are other areas where such "reverse emulsions," "inverse phase emulsions," "dirty waters," or "oily waters" are found.

These emulsions differ from cut oil in that, while they comprise a mixture of crude oil and water, the oil is in the form of droplets and the water constitutes the continuous phase or body of the emulsion. Consequently they behave predominantly like water, just as cut oil behaves principally like oil.

Emulsions of this type are commonly encountered in older fields, where the race between the operators and encroaching water results in higher pumping rates. Wells making larger proportions of water, in fields where the waters are relatively soft and possibly somewhat alkaline, frequently produce such stable oil-in-water emulsions. In general they appear to be produced later in the life of a well than do water-in-oil emulsions.

Their occurrence is not limited to areas producing the black low-gravity oils although they do occur often with this type of crude. Some fields producing oil of well over 30-deg. API gravity show emulsions of this type carrying as much as 5 per cent or more of oil emulsified in water.

Natural oil-in-water emulsions are generally more unstable than natural water-in-oil emulsions, in that standing for periods of from several hours to several days will frequently reduce the oil content of the emulsion to low levels. Cut oil on the contrary sometimes stands for years without appreciable resolution.

The oil-in-water emulsions encountered in oil production differ from cut oil in certain other respects. Whereas cut oil usually contains appreciable proportions of oil, oil-in-water emulsions are commonly quite poor in oil. In many cases, 1 per cent will cover the oil contents of such emulsions and many of them contain only in the neighborhood of 0.1 per cent oil, or 1000 parts per million. Few contain more than several per cent of oil. Because of such low oil contents, the cleaning of such waters results

*"Observations on the Chemical Demulsification of Crude Oil," by Louis T. Monson, *The Petroleum Engineer*, September, 1946, page 69, and "Laboratory Testing of Emulsified Oil," by Louis T. Monson, *The Petroleum Engineer*, November, 1946, page 67.

FIG. 1. First section of settling basin system.

FIG. 2. Final section of settling basin system.

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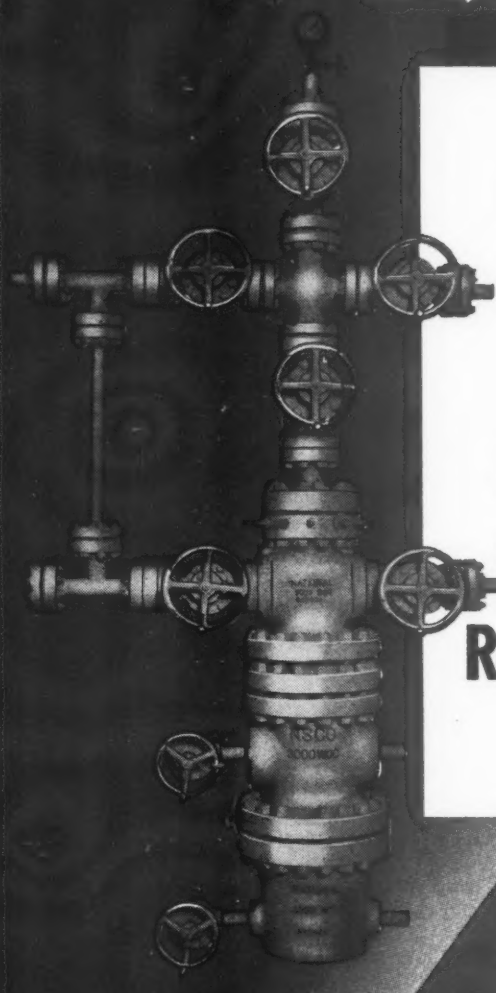

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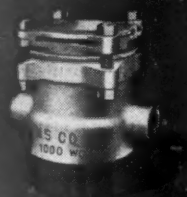

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FIG. 3. Well liquid spilling into production sump comprises oil and oil-in-water emulsion.

FIG. 4. Effluent from oil-in-water emulsion-treating system is clear water.

in the recovery of relatively little oil. In fact, many producers have tolerated the problem for long periods of time and have discarded their dirty waters without treatment because they felt that oil recoveries were so small as to make treatment uneconomic.

Unfortunately neglecting the problem is not always possible. Oily water is a menace to aquatic and other animal life if discharged into surface water courses. Films of oil on stream surfaces seal them and alter delicate chemical balances that exist beneath them. Cattle have been killed by drinking such water. Wild fowl alighting on oil-coated waters absorb the oil and are destroyed. Even though an oil slick may be so thin as to show only the "rainbows" of diffraction effects yet it may be of sufficient volume to constitute distinct fire hazards in harbors or other relatively quiescent collecting zones.

Various governmental agencies are therefore interested in restricting the aqueous discharges from oilfields to surface streams and the ocean to clean water, for one or more of the foregoing reasons. Sometimes, issuance of court orders to abate the nuisance may be threatened even though only as little as 100 parts of oil per million of water (1/100 per cent) is present, or the producer may be faced with bills for destruction of livestock. Ultimately the lease faces suspension of operations if the intolerable situation is not corrected.

The problem became especially acute during the recent war years. Production practices could no longer be conducted within the limits of sound engineering principles. Instead of controlling production rates to give maximum ultimate recoveries it was necessary to produce as much oil as possible and as quickly as possible. Storage facilities predicated on systematic withdrawal at normal rates proved inadequate when the wells were operated at higher rates. For example, one field that had been producing about 5000 bbl. a day of oil was operated to produce about 20,000 bbl. a day. Water production jumped from about 8000 bbl. a day to about 100,000 bbl. a day, as a consequence. Sumps and tanks designed to handle the earlier production volume could not handle the larger volume in the same period of time and accomplish satisfactory separation of oil from free water, even if the oil-in-water emulsion had been identical with that formerly produced.

But it was not the same water. Pumping speeds had been increased and the degree of emulsification of oil in water had consequently been increased. Well servicing schedules became ragged because of shortages of men and replacement parts. Labor shortages also lowered the quality of well and production inspection and wells consequently operated in bad shape for longer periods than usual before detection of such bad conditions. For all these reasons, the water produced was "worse"—a more stable, more refractory emulsion of oil in water.

The problem was an especially difficult one under war conditions. Because the oil recovery from treating possibly 20,000 bbl. a day of water might be a paltry 10 or 20 bbl., close supervision of the operator was improbable from the profit-motive standpoint. Such attention as was given the problem was therefore focused on the delivery of clean water to waste to meet legal specifications.

While oil-in-water emulsions commonly carry only low percentages of oil and although such oil contents may be further reduced by relatively short settling, even 1000 parts per million (0.1 per cent) is usually an intolerable oil content. This small proportion of oil is readily apparent in a water stream because it occurs in the form of small droplets. These impart a strong haze to the water, even when the oil content is very low. As the oil is usually brown or black, as little as 50 parts per million may suffice to impart a yellowish color to a waste water stream several inches in diameter. As the oil concentration increases the water becomes progressively more hazy and more dark-colored until waters are obtained that are not distinguishable from oil in color.

Although the viscosity of such concentrated oil-in-water emulsions is somewhat greater than that of water, the increase in viscosity with increasing concentration of oil phase is not so pronounced as in the case of increasing water contents in water-in-oil emulsions. Possibly this generalization unconciously reflects the fact that the oil contents of such oily waters are usually much lower than the water contents of emulsified oils.

Lighter oils produce relatively less stable and lighter-colored emulsions but an experienced observer can make a reasonably good estimate of the oil content of an oil-in-water emulsion by merely observing the color of an effluent spill of a water disposal system.

The presence in the water of fine clays or silt arising from the formation is sometimes a complicating factor in treating oil-field waters. In absence of oil such mineral solids themselves impart a hazy appearance to water, which resembles the effect produced by low oil contents. Furthermore the clay, in spite of being generally hydrophile in character, sometimes carries an appreciable portion of the total oil content of the water. Oil-impregnated clay is very difficult to de-oil although it may be susceptible to flocculation by the reagents more recently applied to the problem.

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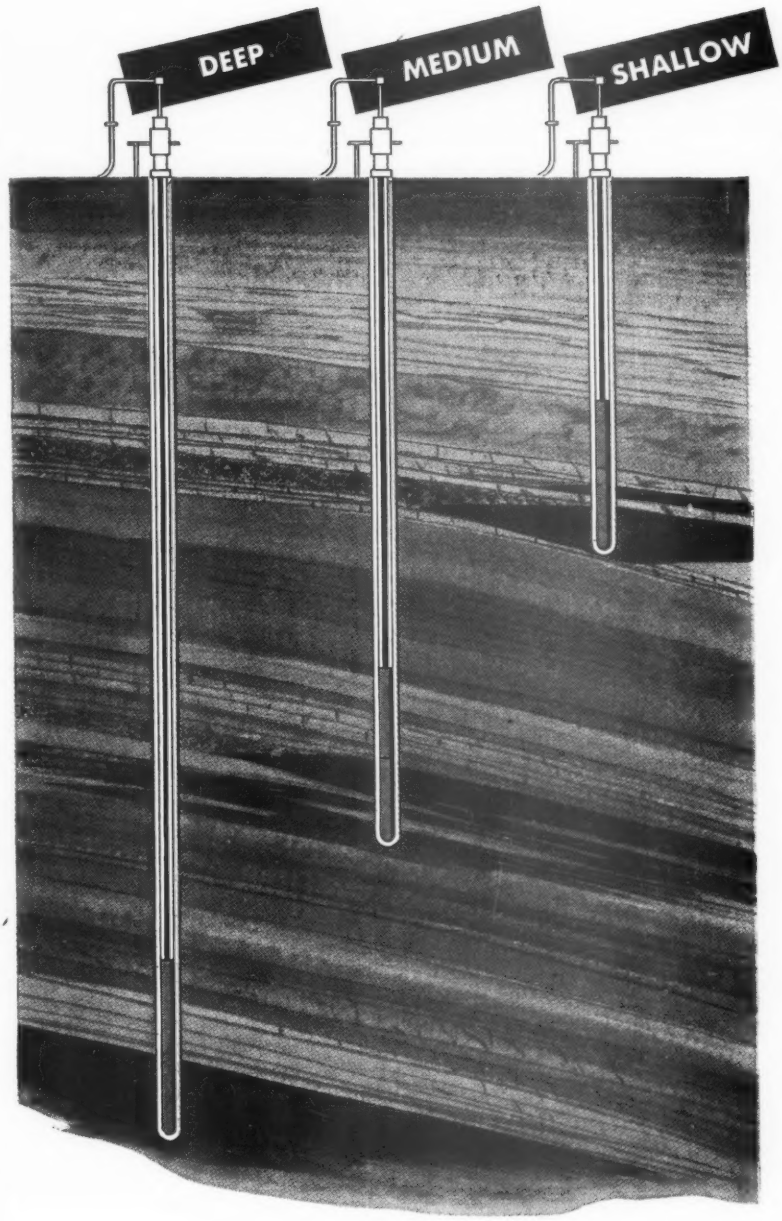

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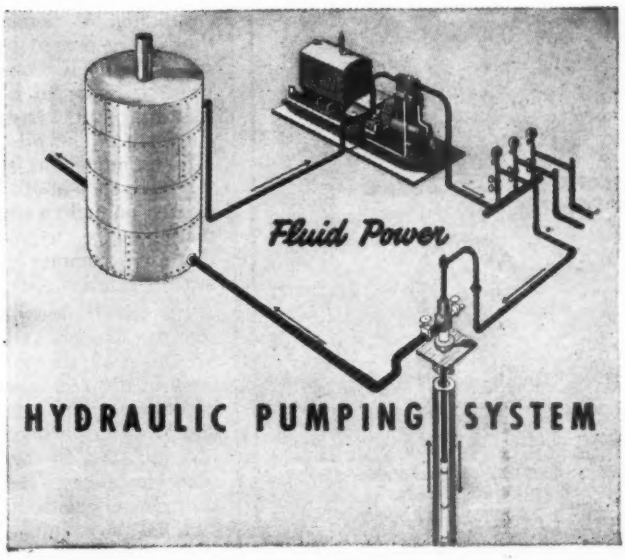

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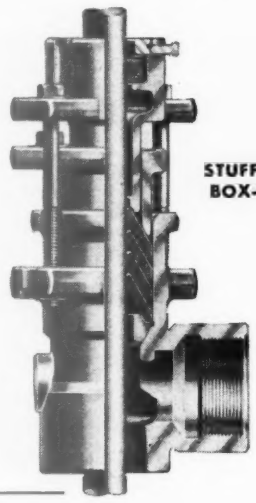

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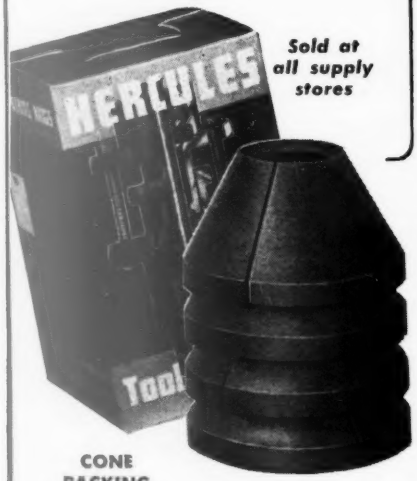

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Clay-like solids have densities averaging greater than 2.0. Oil has a density usually appreciably less than 1.0. Mixtures of the two may therefore possess densities greater or less than that of the water with which they are associated, for oil-field waters usually have densities slightly greater than 1.0. Therefore the oil-soaked clay particles may rise to the surface, sink to the bottom, or, more rarely, remain suspended in the water. Sometimes they collect at the surface but readily become dislodged by slight shock or motion, and then settle to bottom.

The first approach to the problem of cleaning such waters of their small oil contents was mechanical, in that longer settling times or more elaborate skimming or separating devices were provided.

In spite of the fact that most of the oil may separate from an oil-in-water emulsion in a relatively short time, the last portion of the oil tends to remain indefinitely suspended in the water, and even though a water finally contains only 100 parts per million oil, it may exceed permissible oil content limits. Furthermore the volume of water produced may be so great that the settling time available is too short to effect satisfactory separation of water and oil.

Therefore it was concluded that some additional means would be required if acceptably clean water was to be discharged to waste within the time limits available. The first and obvious approach, enlarging settling facilities, proved inadequate to solve the problem.

When this failed, producers borrowed the chemical techniques of municipal water purification systems, and used hydrolyzable iron or aluminum salts like ferric chloride or "alum" to produce a floc. This floc in rising to the surface or settling to the bottom acted as a filter, sweeping the oil particles with it, and so clarifying the water. Because iron chloride and alum are cheap heavy chemicals, this approach to the problem might at first glance appear to be a logical one. The acidic properties of ferric chloride soon became apparent in the extensive corrosion of reagent injection equipment. More important, it was found that oil recovered by such floc-forming reagents itself constituted a problem when it came to be processed in oil-treating plants for resolving water-in-oil emulsion. (The oil recovered from oil-in-water emulsions is sometimes an emulsion of water-in-oil. At least it usually carries enough water to prevent its direct passage to clean storage. It is therefore commonly handled with the wet oil production.)

Electrical dehydration plants responded quickly and unfavorably to the presence of the metallic floc electrolytes in the recovered oil. Chemical dehydration plants produced detectably poorer results when floc-and-oil salvage was included in their charge stocks in some instances. The floc itself was a voluminous gelatinous mass, which accumulated so rapidly that cleaning of sumps became a constant problem.

If free from such metallic floc the oil would have had the value of any other oil and its recovery cost could have been offset by such value. The disposal of oil-floc masses imposed a burden of as much as $50 a day at one location, where it was being burned or trucked away. In some cases sumps were required to be rebuilt after repeated attempts to keep ahead of floc accumulation had failed.

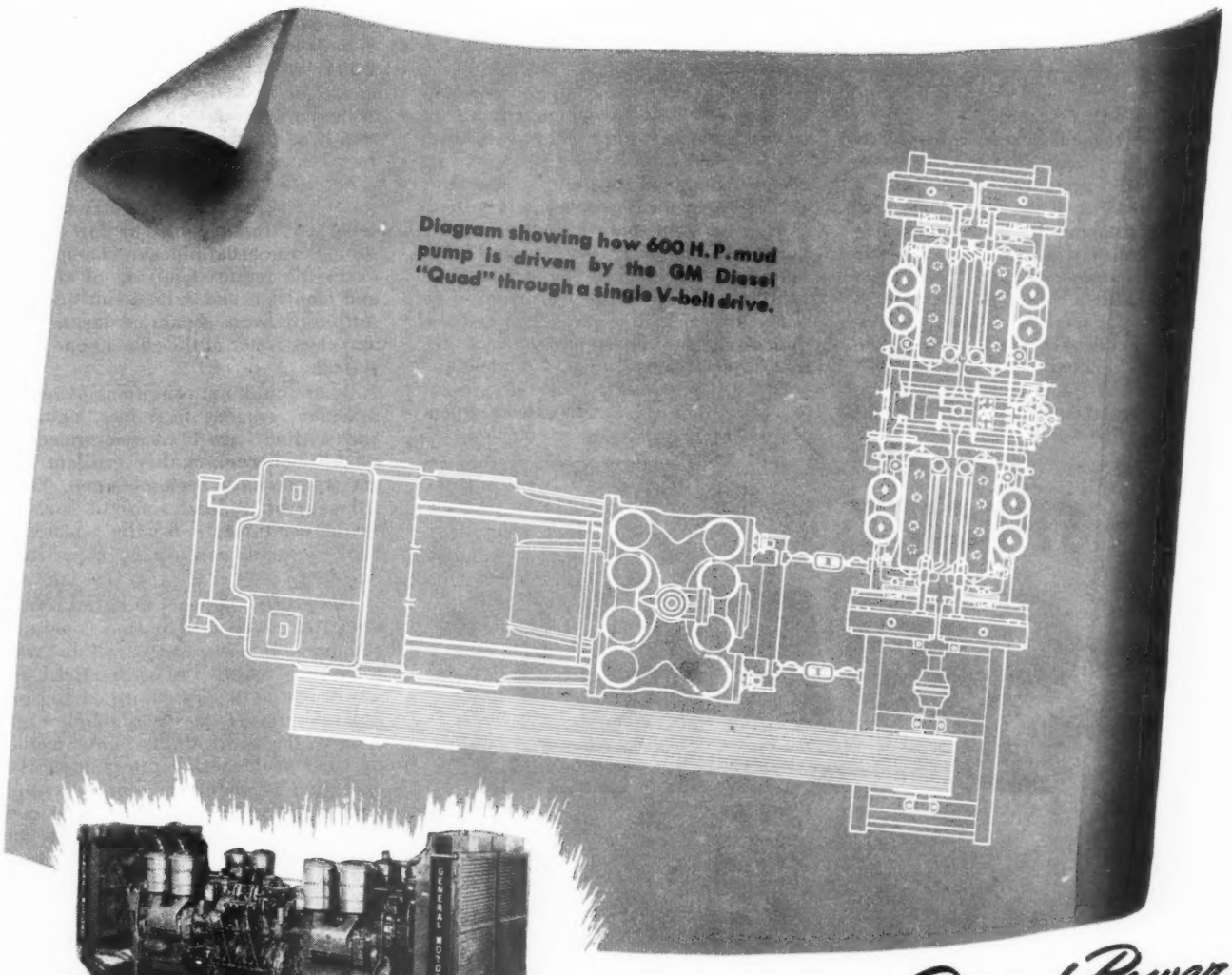
When approached from another chemical viewpoint the problem was solved by application of several proprietary chemical reagents of undisclosed but complex composition. These reagents were found to be effective in separating the oil with satisfactory completeness, rapidity, and cost. The oil so recovered has been processed regularly with other wet oil without ill effects, in the conventional oil-treating procedures, chemical or electrical. The reagents are entirely different from those employed commercially to resolve water-in-oil emulsions.

Fig. 1 shows a section of one crude oil-in-water demulsification system. This is a close-up of the first section of a series of basins and shows chemically-treated emulsion entering the system. Note that most of the oil separates in this first compartment and that the next section, just visible at the left-hand side of the cut, shows no surface oil layer. Fig. 2 shows the substantially clear effluent from the upper sections of this system entering a final settling basin.

Figs. 3 and 4 show another location where oil-in-water emulsions are being treated by the method described. Fig. 3 shows the production from well flow lines spilling into the production sump. Most of the production is dark-brown oil-in-water emulsion, which is drawn from beneath the oil surface in this sump and passed through a series of separating basins until clear water is discharged, as shown in Fig. 4. About 18,000 bbl. a day of water is processed in this system.

A number of factors influence the efficiency of the chemical demulsification process, and the level of oil removal attainable. The design of the treating system and its adequacy as to size, the selection of proper injection point for the reagent, and the proper adjustment of reagent feed rate are all important. As the process has had to become established under pressure of circumstances and in relatively short time, improvements were later effected in some early installations. It became apparent from the first field operations, however, that waters containing originally from 1000 to 10,000 or more parts of oil per million parts of water can be cleaned in routine fashion to oil levels of the order of 5-50 parts per million, or less. Treated effluents are transparent and colorless when the process is properly applied in an adequate plant.

The amount of chemical demulsifier required to be used is generally more favorable than in the case of resolving water-in-oil emulsions. As little as one part of demulsifier to 80,000 or 100,000



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parts of oil-in-water emulsion will sometimes produce optimum results if oil contents are rather low. The cost of reagent at this rate is less than 0.1 cent a barrel of water treated.

As these reagents clean the water to such low levels and with such small consumption of reagents it does not take a large oil content in the water or a very large water volume to offset the cost of the chemical used. For example assume the water contains originally 1000 parts of oil per million (0.1 per cent) and is cleaned to 5 parts per million oil. Assume the chemical cost is $2.00 a gallon, the ratio of chemical-to-water is 1:80,000, and oil is $1.10 a barrel. Under these conditions, treatment of 80,000 bbl. of water will require 42 gal. or $84 worth of reagent and will recover about 80 bbl. of oil worth about $88.

When chemical consumption is higher oil recoveries are also commonly higher so that increased chemical cost is offset by increased volume and value of oil recovered. Sometimes as much reagent as 1:10,000, chemical-to-water, is required.

There is commonly an optimum proportion of chemical to water and addition of excess chemical does not improve results if the optimum proportion is already in use. In this respect the resolution of such oil-in-water emulsions differs from the dehydration of crude oil.

Operating procedure of the present process is simple. No elaborate or expensive equipment is required. The chemical demulsifier is metered into the dirty water stream at any desired point by means of a small proportioning pump. Sometimes the reagent is injected at the well-head into the mixture of well fluids. In other cases the reagent is introduced into the water at the head of the waste water system after such water has been separated from the oil. The flow of water through the usual pipes or channels produces the required mixing of chemical and emulsion and subsequent quiescent settling delivers separated layers of oil and clear water at the effluent end of the system.

Where optimum conditions of reagent selection, reagent feed rate, agitation, and settling have been determined and established, remarkably brilliant effluent waters have been obtained. Establishment of at least some of such optimum conditions is usually a matter of field experimentation by experienced personnel.

The process appears to have taken its place as a standard part of operating technique in oil production in areas where it is required to be practiced, just as oil-treating is an established and routine operation, today. It is simple to determine the applicability of the method by small-scale or laboratory tests. The operating procedure is simple to apply and to supervise. No expensive or complex mechanical plant is required. And it is profitable or at least very inexpensive to conduct, when oil recoveries of as little as 1000 parts per million are realized. When oil contents range as high as 8000 or 10,000 parts per million or higher, as they sometimes do, the operation is not merely a means of resolving a nuisance but becomes positively profitable to the producer.

For example, the procedure is currently being credited with recovering 350 bbl. a day of oil from the water produced from a group of 8 wells in one area. The chemical consumption is 10.5 gal. a day, the ratio of reagent to emulsion is about 1:30,000, but the oil content of the water is unusually high. As the chemical cost is only slightly over $20 a day the net effect of the operation is a healthy profit for the operator.

The process is expanding its usefulness and is resolving other oil-in-water emulsions. In refineries, steam cylinder emulsions, separator or trap recovery emulsions, cooling waters, distillate contacting emulsions, Houdry barometric condenser water, etc., are being subjected to chemical demulsifiers. Absorption oil-in-water emulsions in gasoline plants and emulsions occurring in gas dehydration systems have also responded to application of such reagents.

"White water" is commonly a symptom or signal of the presence of oil-in-water emulsions. Many of the applications of the present reagents have come from their ability to separate such milky water systems completely into clear water and free oil without undesired by-products and with a minimum of equipment and operating expense.

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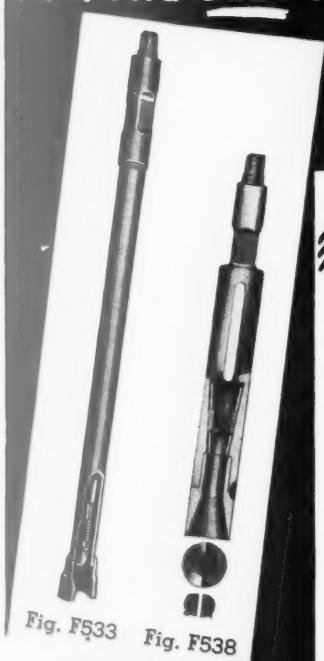

Fig. F533 Fig. F538

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(Fig. F533)

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(Fig. F538)

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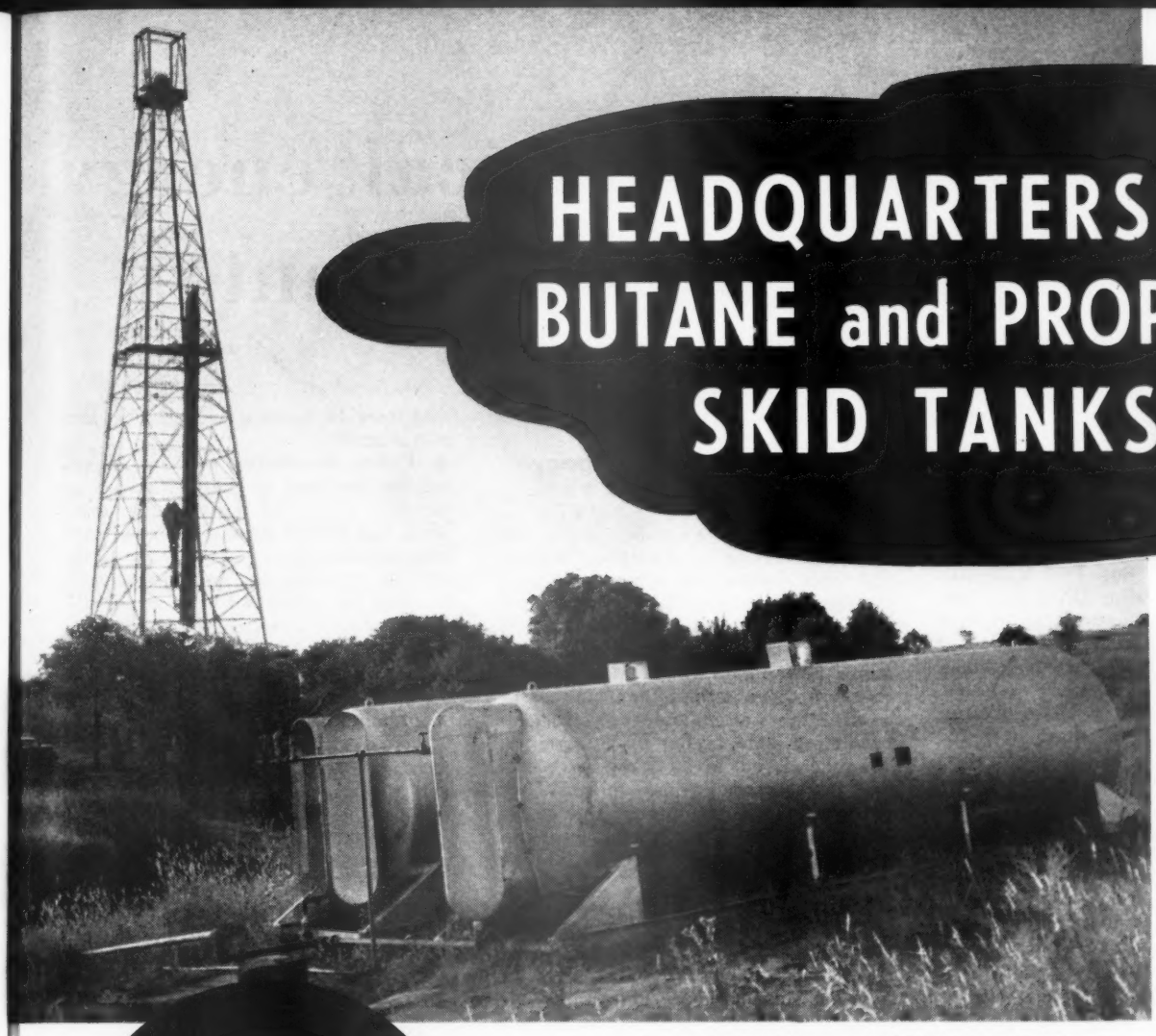

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Utilization of electrical energy in natural gasoline plants*

By **H. S. DAVIS**

General Electric Company

AT THE last meeting, your President, Mr. Marion Arnold, presented a paper entitled, "The Investment Value of Injection Gas." Only a few weeks ago a lengthy analysis came to my desk carrying the title, "An Engineering Report On Gas Repressuring and Recycling," which was prepared by our Petroleum and Chemical Engineering Division. These are only two, and many more of such articles have appeared during the last few months in oil industry magazines. True, there have been papers prepared, and minor attempts to put into practice such teachings over the last 20 years, but admittedly the activity now is at an all time high.

What does this mean? Well, for one thing it may mean more careful scrutiny of natural gas consumption. Many companies that in the past have taken their gas requirements from the "dry line" without any bookkeeping are now charging themselves anywhere from 10 to 15 cents per 1000 cu. ft. The combination of costs and prospective demand for repressuring and cycling indicates that consideration is in order for the use of electrical energy to perform the multitude of pumping and other auxiliary jobs around the absorption plant.

In order to prepare you for that contingency, tonight, in one easy lesson we proposed to give you your B.S. degree in electrical engineering as it concerns natural gasoline plants with prospective connected electrical loads of from 150 to 350 hp.

In making this approach we will consider the plant electrification from the standpoint of (1) Power supply, (2) power distribution system, and (3) power utilization equipment.

● **Power supply.** In order to provide satisfactory service, it is necessary that the power source be not only adequate, but also reliable. To provide adequacy, the system must be capable of supplying the maximum demand of the plant and at the same time maintain its voltage and frequency essentially constant. Reliability is obtained when the power source contains sufficient standby equipment so that there will be no interruption of service in case any of its component parts are removed from service for inspection or repair.

The majority of industrial plants, particularly those having small power requirements, purchase their power from public utilities. This is the logical result, when the rates are favorable, of the greater economy of operation of large central stations over smaller plants that would satisfactorily serve their individual requirements, and of the greater reliability that comes about through the interconnection of several generating stations. There are in California 150 major power plants with a capacity in excess of four million horsepower. In number the water plants exceed steam generation stations, but in capacity the difference is not great. We have, therefore, two sources of prime energy: Water power from the mountains and steam power from products of the petroleum industry, particularly the natural gas division.

The reliability of utility power supply is further insured by interconnections that make it possible to make a metallic connection of power plants reaching from the Mexican border, north through California, Oregon, and Washington and east to Idaho, Montana, and Utah. It is almost impossible to find an industrial district anywhere in the state that does not have at least two separate sources of electric power, which means that in the event of any emergency that would cripple a power line, another is immediately available.

I think it would be entirely in order at this time to cite an example of close cooperation between the power companies and the petroleum and natural gas industry. In February, 1944, a program was developed at a meeting of electric utilities, oil and gas companies, War Production Board, and the Petroleum Administration for War that cut the use of fuel oil vitally needed by the government by approximately 50 per cent. The program also set up the Edison steam plants to operate as a regulating valve for the Southern California gas systems, increasing and decreasing load to enable the gas transmission lines to operate at full capacity at all times. In turn this made it possible to operate oil wells at full output continuously without wasting or blowing gas.

In our consideration of power supply we should not neglect mentioning the fact that conditions may exist that call for some consumers to generate a part or all of their power locally. The economics and technical aspects require careful engineering treatment and each particular case must be treated separately. Engines or turbines, fuel, process steam requirements, etc., are all factors that must be scrutinized before a decision is made.

● **Power distribution system.** Assuming for now that we have procured an adequate source of power, what next? Well, this merely brings us to the back fence of our plant; now we have to decide on a proper distribution system to transmit the power we have at our disposal to the various individual loads throughout the operating area. Under normal operating conditions, the voltage at the load should not vary more than about plus or minus 5 per cent from normal. At the same time the voltage variation of lighting circuits must be held within such limits that objectionable flicker is not present.

The distribution voltage is one of the first factors to be considered in laying out the distribution system. It is materially affected by the size of motors that are to be operated, the total kva. load, and the area over which the power is to be distributed. As the possibility of any motors over 100 hp. is remote in our absorption plant, the logical voltage for use at the machine is 480; however, in distributing throughout a process area, the voltage of 480 might easily be found to be too low. The higher the voltage, the less current must flow to transmit the same power, and the less current flowing the smaller the permissible copper size.

Fig. 1 illustrates what the relative cost of the cable is to transmit 1000 kva. at three different voltages.

Therefore, instead of moving all our power around the plant at 480 volts, it might be well to consider distributing at higher voltages, either 2400 or 4160, to centers of load and then stepping down to our 480-volt utilization voltage.

The one line diagram shown in Fig. 2 is a workable solution to our distribution requirements but it does have shortcomings. It is not entirely inflexible, for it is fed by three single phase transformers and one of these could be removed in case of trouble and service restored in a matter of hours. If service was made at higher than 4160 volts it would be unwise and contrary to California code to carry this high voltage into the plant area and consequently this would mean all the distribution at 480. Breakers could be coordinated so that any feeder trouble would clear without bothering the main low voltage breaker.

The one line diagram shown in Fig. 3 makes possible working on equipment, and certainly provides the highest type of dependability. As we are receiving power at 2400 or 4160 volts, the incom-

*Presented before the California Natural Gasoline Association.

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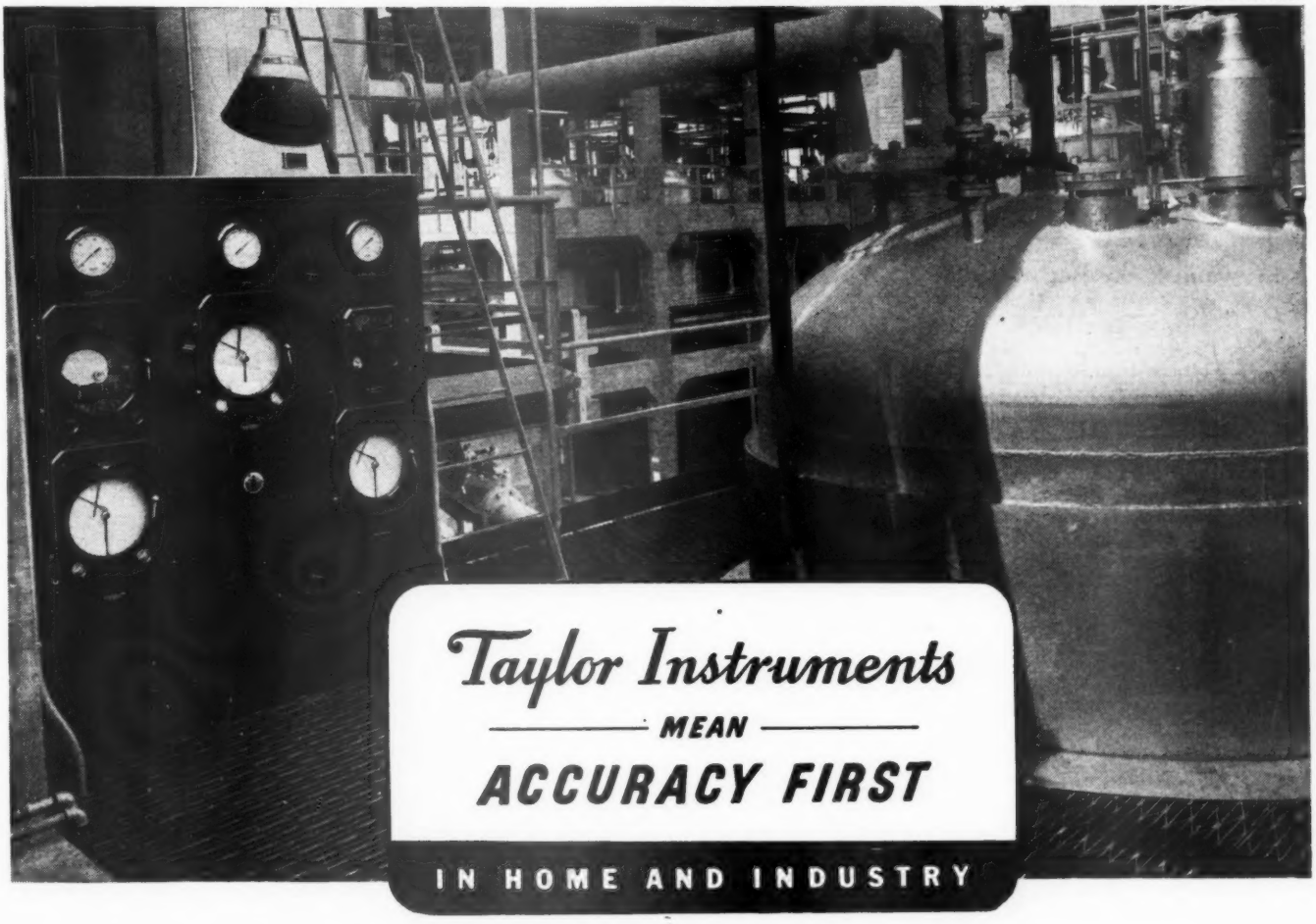
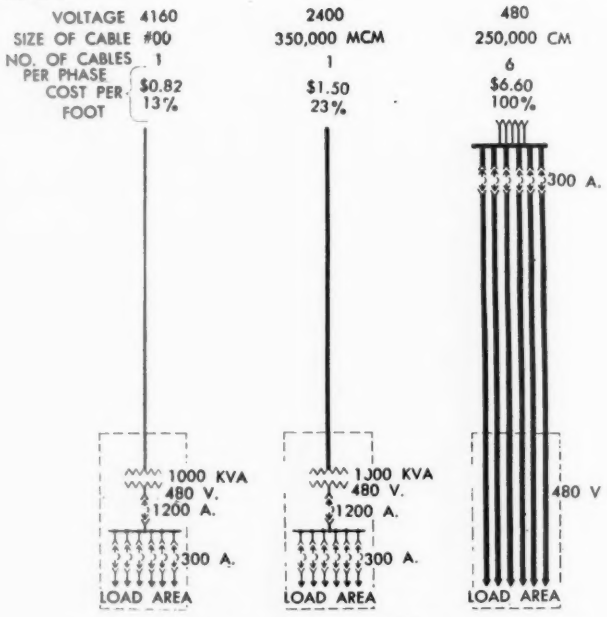


FIG. 1



CABLE SIZES SELECTED ON CURRENT CARRYING CAPACITY ONLY

FIG. 2

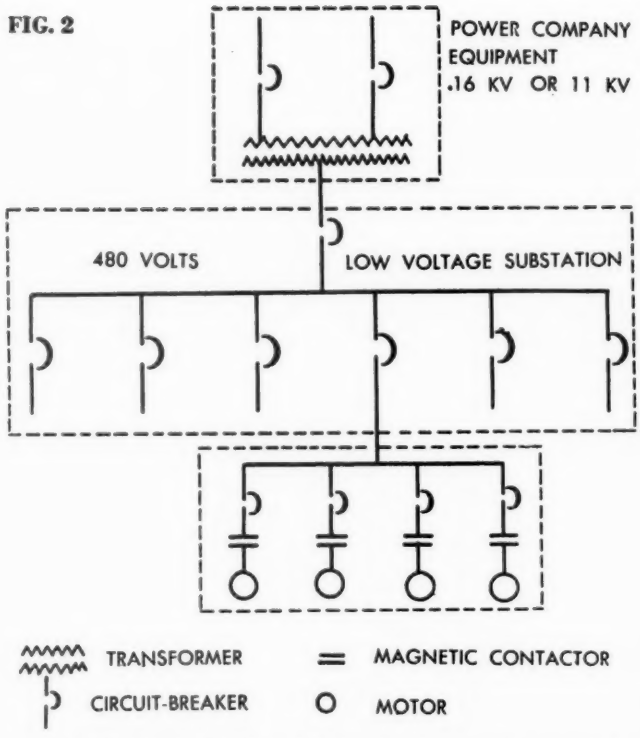


FIG. 3

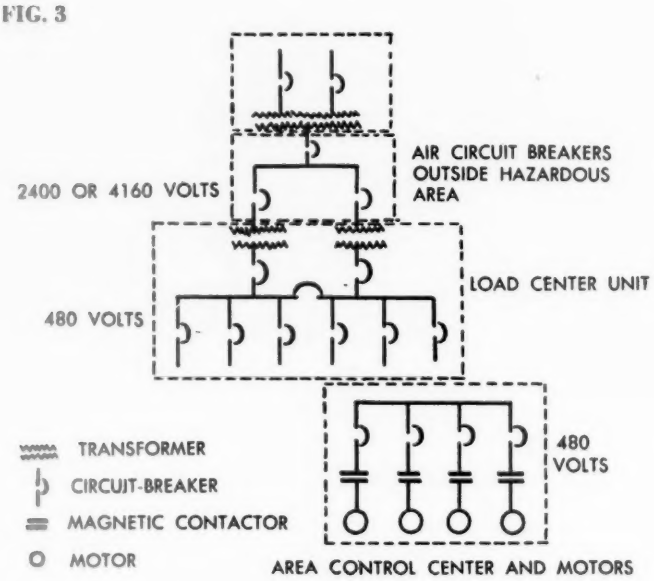


FIG. 4. Voltage drop in secondary feeders.

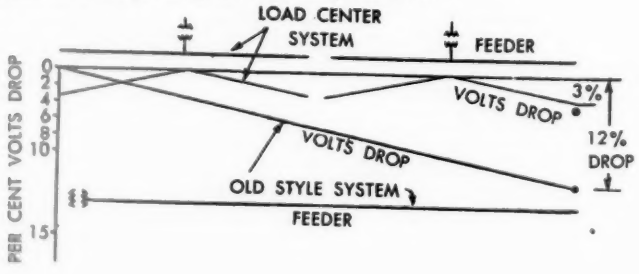
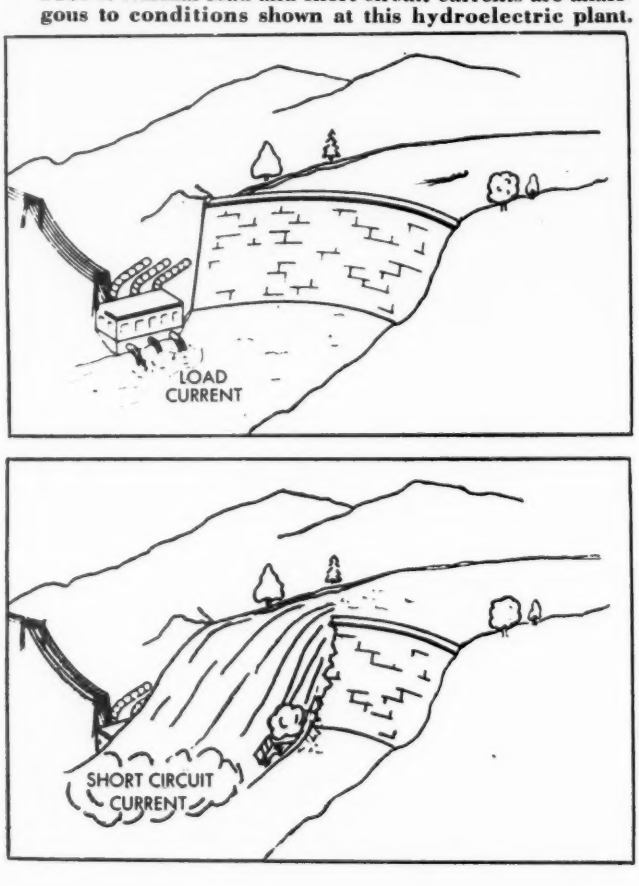
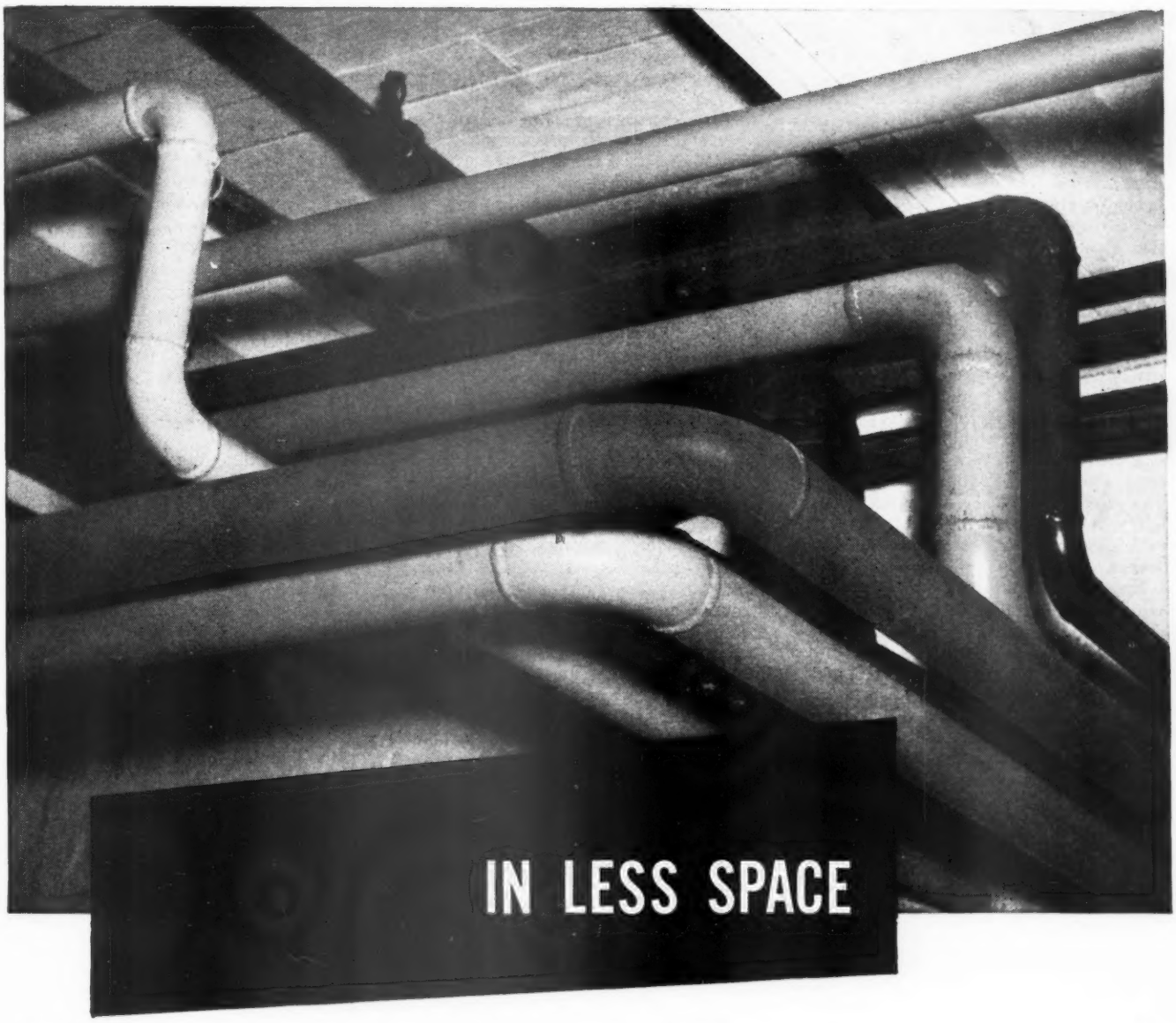


FIG. 5. Normal load and short-circuit currents are analogous to conditions shown at this hydroelectric plant.



ing switchgear may be placed outside the hazardous area and the two feeders to the load center units may make lengthy runs without any concern as to voltage drop. And, if we were to look at the voltage drop, Fig. 4 shows this rather graphically.

It may seem like we are placing undue emphasis on the distribution system, but since we are talking about continuous flow processes such as exist in natural gasoline plants, the factor of service reliability is of utmost importance. One of the most serious electrical disturbances that might endanger our well-planned reliability is the short circuit. Short circuits may occur at any point throughout the power system. The usual cause is breakdown of insulation because of mechanical failure, overvoltage, or some other circumstance impossible to anticipate. For minimum system disturbance the affected circuit must be disconnected from the distribution system with great speed by circuit breakers with adequate interrupting capacity, more often referred to as "I. C."



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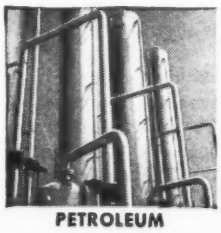
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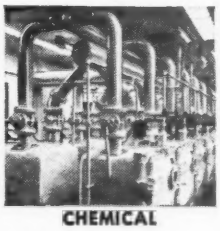
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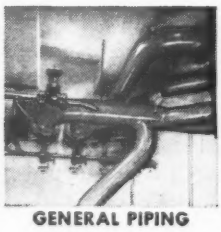
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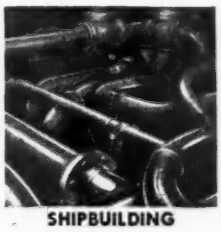
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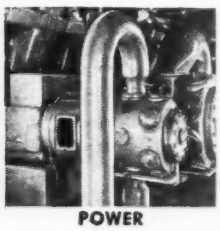
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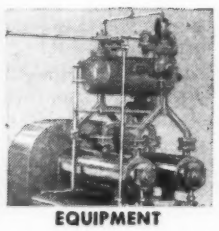
EQUIPMENT

A hydraulic analogy, as shown in Fig. 5, will serve to illustrate what is meant by short circuit and give us a better idea of what we have to interrupt. The amount of water that flows under normal conditions is determined by the load on the turbines. Within limits, it makes no difference whether the reservoir behind the dam is large or small. This flow of water is comparable to the flow of load current in the distribution system of our absorption plant. On the other hand, should the dam break, the amount of water that will flow will depend upon the capacity of the reservoir, and will bear no relation to the load on the turbines. Whether the reservoir is large or small will make a real difference in this case. This flow of water is comparable to the flow of current through a "short" in the distribution system. The load currents do useful work, like the water that flows down the penstock through the turbine water wheel. The short-circuit currents produce unwanted effects, like the torrent that rushes madly downstream when the dam breaks.

Fuses and circuit breakers are used to open a faulty circuit to stop the flow of short-circuit current. These devices have two ratings, the first is their normal full load current, and the second is interrupting rating or ability to open short-circuit currents. The more transformer capacity installed, and the larger the power supply feeding the transformers, the higher are the potential short-circuit currents.

Summarizing for a moment, what have we attempted to achieve in our distribution system? (1) Service reliability, (2) Good voltage regulation. (3) Operating simplicity. (4) Safety. With a workable plan incorporating these four features we are now ready to proceed to the utilization equipment.

● **Power utilization.** Next in the sequence of our progressive power analysis is the consideration of motors and control. These, after all, are the basic units that make possible the use of electricity for the various pumping services that we might consider. Moving on again from the 480-volt side of our load center units, shown in Fig. 3, each of these six circuits may feed a single motor or a group of motors depending on their size. For our hypothetical case, however, let's consider only one circuit and assume that it runs to a group of starters serving motors ranging in size from 10 to 25 hp.

Remember, with our load center units we had the choice of using explosion-proof switchgear or placing it in a pressurized room. Once again this decision must be made for the motor starters. If it is possible to separate the operating area from the plant service area explosion-proof equipment may be replaced by standard equipment in the pressurized rooms. However, for the purpose of our discussion let us assume that explosion-proof equipment is called for. In its present form, this may or may not be housed. Essentially, this problem reduces to a consideratoin of maintenance costs against building costs.

Each of these explosion-proof starters contains a circuit breaker, overload relays and magnetic contactor.

Before continuing our discussion in this vein, it might be well for us to orient our thinking on what is meant by a hazardous location. Under this general classification, the National Electrical Code defines Class I hazards as those conditions that involve flammable gases or vapors. As the rate of flame propagation and maximum explosion pressures varies widely, Class I has been further subdivided and the group that represents absorption plants is Group D. Included in this group is high-test gasoline, acetone, alcohols, benzine, benzol, kerosine, lacquer-solvent vapors, methane, naphthas, natural gas, petroleum distillates, toluene, turpentine, and many others.

Based on this gaseous condition, the Underwriters' Laboratories and electrical manufacturers have decided that it is impracticable to design gas-tight motors and control. Therefore, it is assumed that explosions will occur within the enclosures, either through failure of a winding or bearing, or through normal arcing or sparking of contacts. The construction must withstand such an explosion of a specified gas and must prevent the passage of dangerous sparks or flame from the interior to the surrounding atmosphere.

From the control standpoint we can talk either oil-immersed or air-break, and the oil-immersed has different requirements, which call for arcing parts to be immersed in oil to a minimum depth of 6 in. and a visible oil-level indicator.

The motor design requirements in order to pass the Underwriters' inspection include several interesting points and I think it would be well to give you these:

1. Casing must have a safety factor of 5 over maximum explosion pressure.
2. Bolt spacing 6 in. maximum, again with a safety factor of 5 and a maximum hole clearance 0.031.
3. ¾-in. rabbet width on joints with maximum clearance of 0.002.
4. Minimum length of flame path at shaft opening 1½ in. with 0.025 maximum clearance.
5. Leads sealed with specified nonsoftening, noncracking compound ⅝ to 1¼ in. depth according to motor size.
6. Conduit box independently explosion-proof.
7. External fans must be of nonsparking metal.
8. No removable plugs in motor enclosure.

These specifications sound quite impressive, but are we sure that they will give us the margin of safety we should have? Apparently someone else wanted to know the same thing, for here is the way motors are tested. The motor under test is subjected to a specified gas or vapor-air mixture over the range of flammable or explosive concentrations, so as to cover the maximum pressure effects and the maximum propagation effects of the specified mixture. To carry out such tests, a motor is installed in a test chamber that is provided with gas inlet and outlet connections. The motor itself is tapped with threaded holes for connection of inlet and outlet pipes for the explosive mixtures, also for spark-producing devices and pressure-recording instruments.

The flammable mixture of accurately determined proportions is allowed to flow through the motor as well as in the test chamber around the apparatus, until all original air has been displaced. The inlet and outlet valves are closed and the mixture inside the apparatus is ignited by spark plugs.

Observations are made to determine the amount of sparks or flames escaping and pressures in various parts are recorded. A minimum series of 15 or 20 tests is conducted over the flammable range, with the motor operating in some instances.

This same testing procedure is applicable to air-break control for it follows quite closely the construction features outlined for motors.

While we are on the subject of motors, let us examine some of the other characteristics. Bearings, for example, are one of the most important parts and the most vulnerable to improper maintenance. Bearings, which are used in most cases up to 250 hp., are either grease or oil lubricated. Oil of course is easily changed or replenished, but with grease we have a different problem. In the recent motors changing is done by "purging," which means forcing grease in at the top of the bearing and letting it out at the bottom. Even when adding the plug at the bottom of the bearing housing should be out so that excessive pressure is not built up in the bearing housing, which in turn forces grease into the motor winding. In the larger motors, which concern us very little in the size plant we are interested in, sleeve bearings are now available and of course are ring or pressure lubricated depending upon the speed. There is one more type of motor that is acceptable in hazardous locations but is applicable only in the larger horsepowers up to 1000, and that is the inert-gas-filled squirrel-cage induction motor with built-in heat exchangers. CO_2, flue gas, nitrogen, etc., are a few that have been used.

In applying motors in hazardous areas one of the most important things to keep in mind is the shaft horsepower required at the pump. This seems like an obvious point, but the fact that is often missed is the fact that totally enclosed fan-cooled motors are able to carry only their rated load and no more. Many people who have worked with shipping pumps, gathering pumps, well pumping jacks, etc., are accustomed to making use of the additional 15 per cent service factor that is built into the standard open motor. A logical question at this point, is, where does the 15 per cent come from? To explain this we must know what is meant by the figure 40° rise that appears on the motor nameplate—40° rise means that the motor under full load conditions is not supposed to exceed a total tem-

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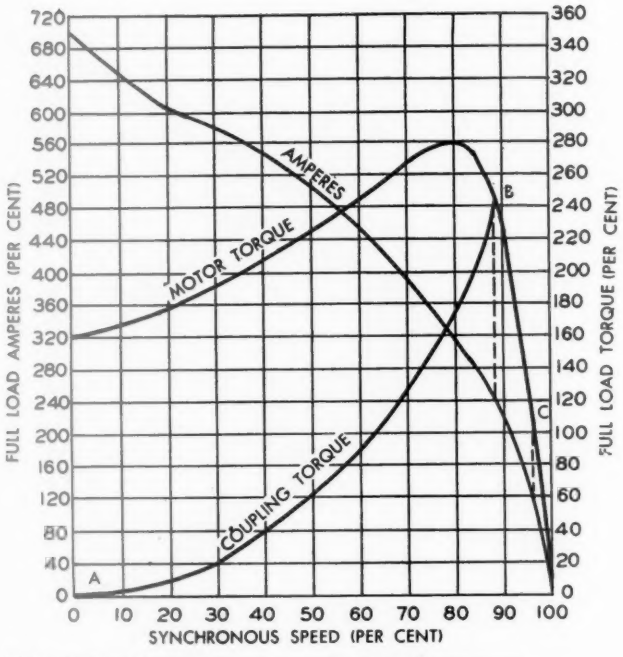

FIG. 6. Performance curves of general purpose squirrel-cage motor connected by hydraulic coupling to load with hard starting characteristics.

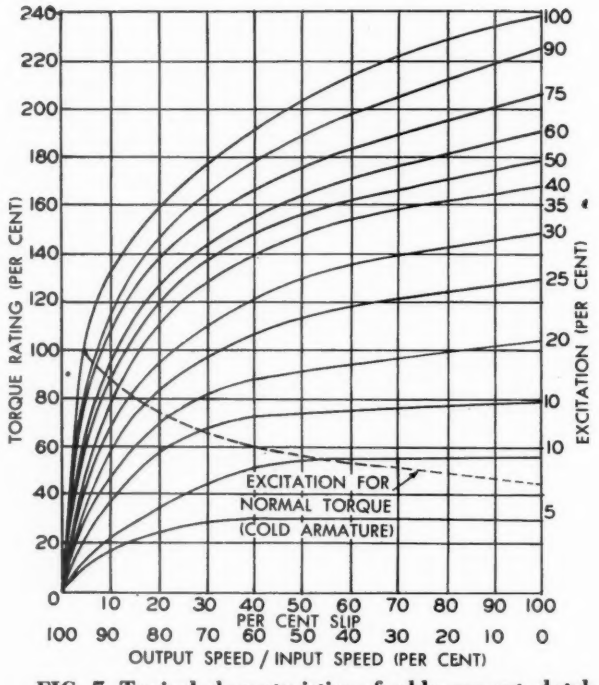
TORQUE RATING (PER CENT)
EXCITATION (PER CENT)
EXCITATION FOR NORMAL TORQUE (COLD ARMATURE)
PER CENT SLIP
OUTPUT SPEED / INPUT SPEED (PER CENT)

FIG. 7. Typical characteristics of eddy current clutch. Curves show relation of slip, torque and excitation.

perature of 40 plus the ambient temperature. This statement is based on an ambient not to exceed 40°.

Under the worst conditions this would mean that the total temperature would be 80° measured on the winding, which is the hottest available part of the motor. Actually, 90° for open motors (or 95° for enclosed motors) is considered the maximum operating temperature for reasonable insulation life, consequently with this 10° leeway we get a 15 per cent permissible addition to the nameplate horsepower rating. Many of us are fooled by the fact that a motor will carry considerable overload without any apparent harm, but by doing so we have materially shortened the time before a rewind will be required.

This explanation has so far been built around the standard open motor, what about the explosion-proof type that we are most concerned about? Well, first of all, in order to keep the size down, all TEFC and Class 1 Grade D motors have been rated 55° rise. This immediately uses up our 10° leeway that we had in the open motor and 5° more. Consequently full load current as indicated on the nameplate is as high as we should go.

Not only does this maximum loading affect the application of the motor, it also affects the proper selection of overload protection that is incorporated in the starter along with the circuit breaker. The current rating of the overload relays should never exceed the full load current of the motor.

● **Motor applications.** Before getting into specific applications I think it would be wise if we reviewed our progress. We have entered the plant through high voltage switchgear with adequate interrupting capacity and divided our supply between two load center units consisting of Pyranol-filled transformers and low voltage circuit breakers that feed each of our motor circuits or groups of motor starters. From here we have followed one of these circuits to a group of explosion-proof starters and from there to the explosion-proof motors.

With this summary, let us proceed now to a wider consideration of the absorption plant. Back in the hey-dey of field discoveries in California these plants mushroomed along with production. Cost was no item, anything to get them in and running. In many instances the pay off was probably less than a year. Under these conditions, equipment efficiency and general plant economy was a secondary consideration. The whole plant accomplished its pumping services by use of the simplex and duplex direct-acting steam pumps. This is no reflection on these work horses of the oil industry, for they have been performing pumping jobs for some 200 years and they still fill specific needs in the absorption process. Earlier use of steam pumps was also called for by lack of design and process information. Under these conditions it was impossible to make a close application of a pump and the flexibility of the simplex and duplex units was a very desirable factor.

In the beginning, absorption plants were primarily designed for producing natural gasoline, which was not too difficult, but as time went by, many refinements were added that made plant operation more difficult. Accompanying this additional complexity, have come centrifugal pumps and motors, whose entry into the field is comparatively recent, probably not over 15 years ago.

With the coming of centrifugal pumps, close-clearance simplex steam pumps have taken over that group of services where high discharge pressures are maintained and the pumping rate is under 100 gal. per min. In fact, in the newer plants I believe we will find about 40 per cent centrifugal and 60 per cent reciprocating.

In any plant where process steam is a necessary commodity, good engineering dictates that it is good practice to throttle higher boiler pressures through steam pumps, and turbines. How far to carry this line of reasoning is a matter for careful scrutiny by each plant management, involving heat balance, fuel costs, and the cost of generated or purchased power. Similarly, if we are to consider multiple-cylinder gas engine drive vs. electric, the factors of gas at between 10 and 15 cents per 1000 cu. ft., power at from 7 mils (0.7 cent) to 1 cent, original cost, installation cost, maintenance cost, and depreciation must all be weighed carefully.

Assuming now that some of our pumps are to be electrified, which ones should they be? At first glance, the centrifugals would be the only ones where this would be economical. Power pumps cost almost 2½ times as much as reciprocating steam so this application would be hard to justify unless we had a particular control problem where variable speed electric drives could be justified.

This brings us to the first aspect of applying a-c. electric motors to pump service. The standard squirrel cage induction motor is essentially a constant speed device, and in order to get variable speed we must either interpose speed changing devices, or we can use special types of motors with variable speed characteristics. The following is a list of speed-changing devices for use with the standard motor:

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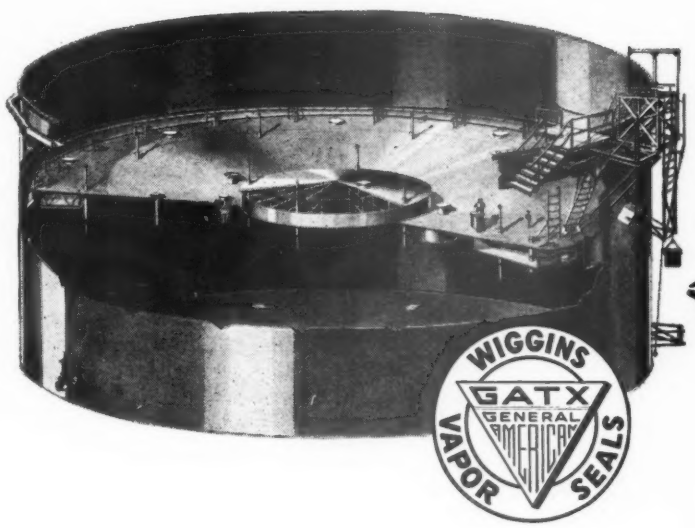

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FIG. 8. Characteristic curves of a constant-torque load.

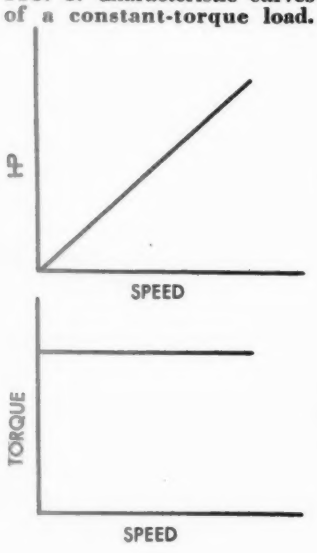


FIG. 9. Characteristic curves of a constant-horsepower load.

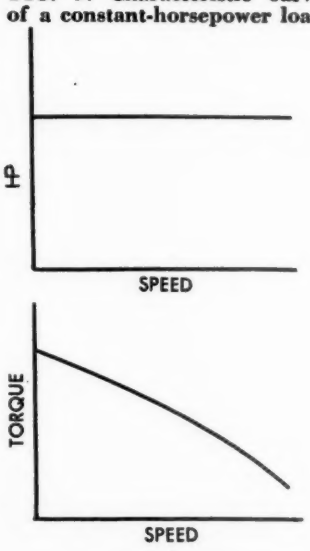


FIG. 12. Variation of power factor with load for a typical induction motor.

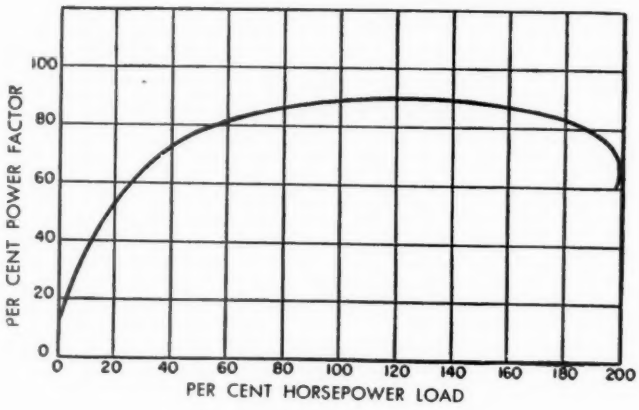


FIG. 11. Amplidyne set.

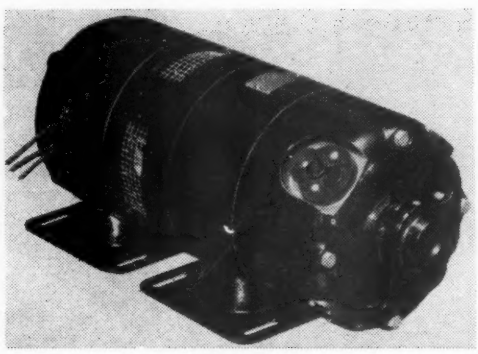
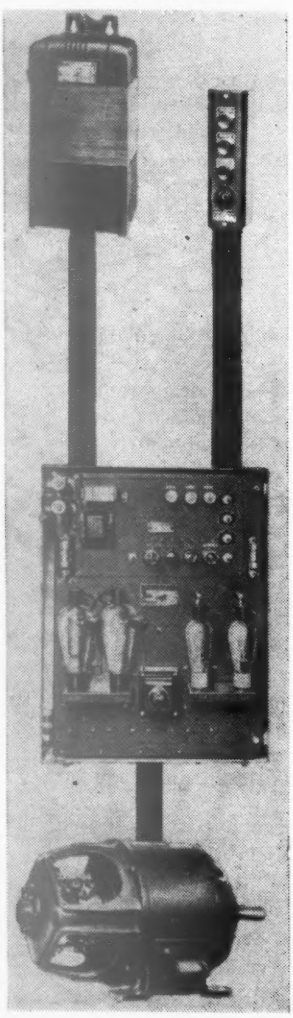


FIG. 10. Thy-mo-trol.



1. Aldrich-Groff controllable capacity pumps.
2. Hydraulic couplings.
3. Electric couplings.
4. Reeves Vari-Speed, Link-Belt PIV., etc.

Commenting on these in order, the Aldrich-Groff pump is a triplex positive displacement type, with 6-in. stroke—100 b.hp. as the maximum size. Pumping against a constant head, by reducing the stroke the driver horsepower should fall off in direct proportion. It is adaptable to automatic control with a diaphragm regulator.

Hydraulic couplings are coming into more and more common usage on pump drives. They can be used on the power pump, but since this is a constant torque load, there is no saving in motor power, because at any reduced speed the difference between the brake horsepower at the pump shaft and the horsepower output at the motor shaft is dissipated in losses within the coupling. On a centrifugal pump, the torque falls off as the square of the speed and the horsepower as the cube of the speed, so, assuming 1 hp. required, at half speed we should theoretically consume only $\frac{1}{8}$ the power. However, half of this, or 1/16th hp., is still lost in the coupling. The curves in Fig. 6 show some interesting relations for the fluid drive.

The electric coupling has practically the same characteristics as the fluid drive with the exception that it is manually variable. (I should say also that a hydraulic coupling is made with manual adjustment.) This of course allows us to pick our accelerating torque as shown in the sample curves of Fig. 7.

The Reeves vari-speed, the Link-Belt PIV, and others use the principle of varying pitch diameter on a close-coupled belt drive. These units are better than 90 per cent efficient and lend themselves to either small power pump or centrifugal pump drives.

It should be mentioned here that any of these drives can be operated with a small reversing pilot motor that is capable of being controlled by temperature, pressure, or flow meters.

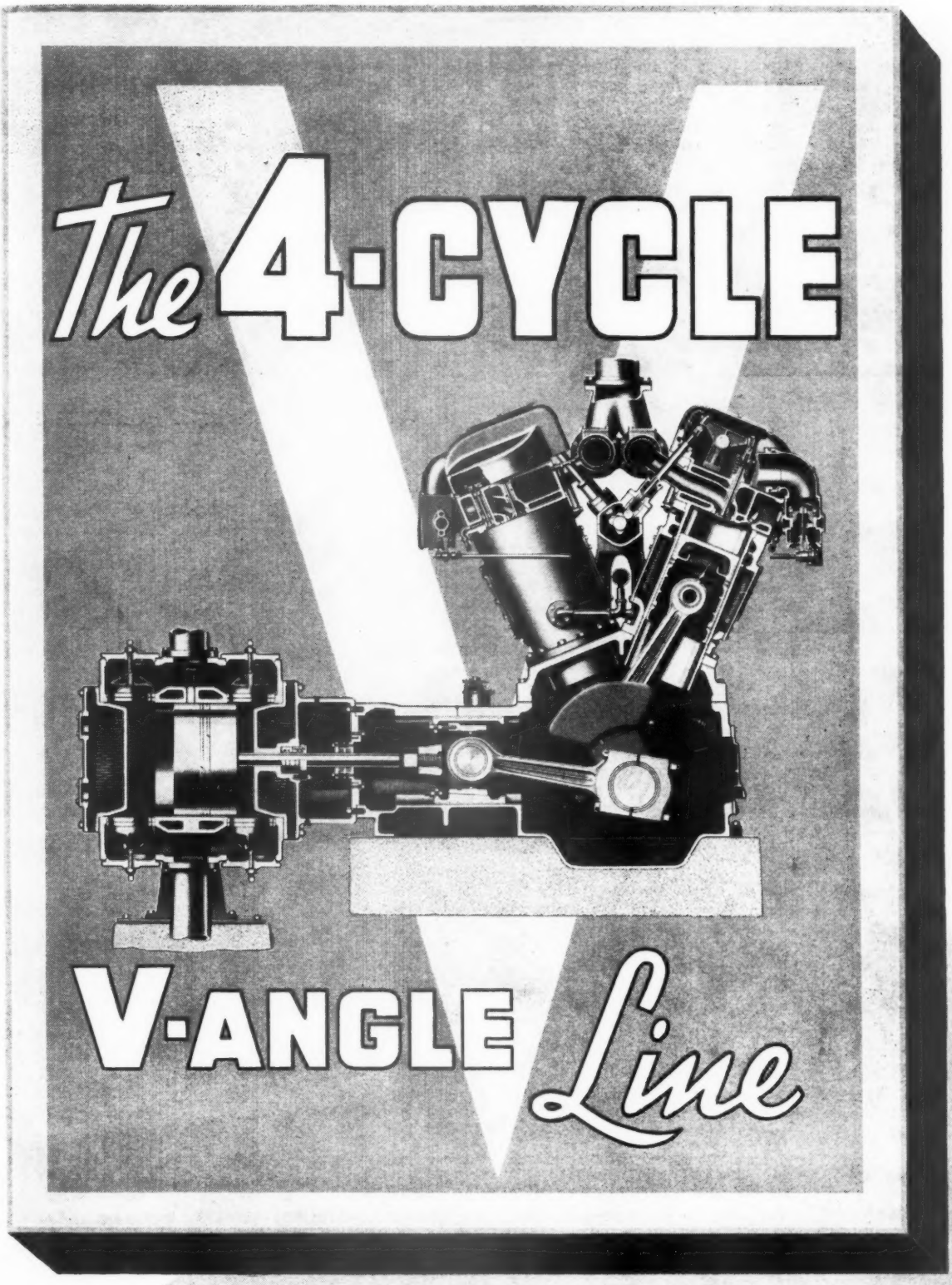
In the field of special motors, there is another group consisting of:

1. Collector ring induction motors.
2. BTA motors.
3. Thymotrol.
4. D-c. motors driven by M-G sets with control by Amplidyne.

Collector ring motors are, of course, one of the oldest in the family of variable speed a-c. motors. Their greatest disadvantage is similar to the electric motor and hydraulic coupling combination, for the horsepower input is constant at reduced speeds when driving a constant torque load and the difference in energy is dissipated in the grid resistors that are in the motor circuit.

The BTA motor is essentially a constant torque machine with an efficiency of about 75 per cent and smoothly variable speed that is accomplished by shifting a brush rigging. Its chief drawback is the fact that it cannot be enclosed. Too high in price for most common pumping jobs, it has been widely used on boiler feed pumps. Here again, pilot motor operation is available to operate in conjunction with any instrumentation.

Thy-mo-trol is one of the newer drives and this new tool of the much publicized electronics field does have remarkable



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versatility in speed and torque characteristics. It might be well at this point to review in our minds what we mean when we say constant torque and constant horsepower. Figs. 8 and 9 give that relationship between torque and horsepower. Either of these conditions or a combination of constant torque and constant horsepower may be achieved with this drive. Fig. 10 shows the combination of units making up a Thy-mo-trol power system.

The control for Thy-mo-trol is stepless and requires only a few milliwatts for operation, which makes it a natural for any instrument work. Its overall efficiency is in the neighborhood of 64 to 70 per cent and this holds up fairly well down to half speed and even below. The control panel is not available for Class I Grade D locations because of the cooling problem; however, the motors and push-button station are, and in most instances this is sufficient.

If we had a number of pumps all requiring variable speed, then more economical than the Thy-mo-trol would be an installation of a motor-generator set to give you a source of direct current and separate d-c. motors on each pump. In the past we have always thought of controlling a d-c. motor by means of a large unwieldy rheostat, usually manually operated, but with wide limits to work in it was possible to motorize. Now, however, a new tool has been added to replace the rheostat, this is a small motor-generator set known as an Amplidyne. Fig. 11 shows a typical unit. Actually, this is nothing more than an extremely fast response especially designed d-c. generator that requires only 1 watt to change the output from zero to maximum and machines are available up to 25 kw. Use of d-c. motors is not new, but the tools that adapt them to the high accuracy control requirements of the present day are. Again 1 watt is well within the power limitations of any standard instrument such as Brown, L&N, etc.

This covers hurriedly the pump application field, and you notice that I have not spoken of standard, constant-speed motor centrifugal pump drives, for I am sure that all of you are aware of the various valves that can be used to throttle the discharge automatically as a function of some system variable.

One important service in natural gasoline plants that we have not mentioned yet is the water cooling system. Cooling towers, whether atmospheric or induced draft, are an essential part of the process. In recent years more of the induced draft units have put in their appearance, partially as the result of space restrictions, and largely because of the need for closer temperature control. With natural draft towers, change in wind velocity or direction is apparent in water temperature. With induced draft towers, variation in cooling rate to meet ambient conditions is accomplished by switching on or off of individual cells and also by using multispeed motors. It is interesting to note at this point that by learning the hard way we have found it is a wise move to use totally enclosed fan cooled motors on this service. The saturated air in the immediate vicinity of the tower does not make for the best insulation life in an open motor.

Probably at this point all of you are wondering how much there is to this monster known as electrification. Actually, there is only one more important point in the consideration of a plant electrical system, and that is power factor. I have written down a few definitions and one fundamental equation:

Fundamental relations

V = volts
A = current (amp.)
P = power
PF = power factor
$P = V \times A \times PF = VA \times PF.$
Good beer $= Q \times PF.$

To illustrate this equation, there is the classic example of a glass of beer. The full height of the glass represents the quantity of beer that flowed through the tap at a certain pressure. However, when the glass is laid on the bar let's say the top 20 per cent of the glass is foam and the bottom 80 per cent is good amber fluid. Therefore, we could say that our glass of beer has only 80 per cent PF. Now we all know that this head varies and so does the PF in a plant.

Power is the only part of electrical energy that can accomplish useful work, so that is what we are interested in getting to the motor terminals. Looking again at the equation, we can assume that the voltage remains constant, and we might have tremendous currents going through our cables, but if the PF isn't high little turning effort is exerted at the other end. What is the importance of this phenomenon? Just this: transformers, cables, and generators are rated on their current-carrying ability and if large values of current are passed through these devices at low PF then we are not getting the work out of them we should.

Motors demand from a system, electricity that is not 100 per cent power factor, in fact, it is usually about 80 per cent at full load. To correct this we install capacitors at or near the motor. In Fig. 12 is shown the value in the proper selection of induction motors. Anything under 100 per cent of rated horsepower has drastic effects on motor PF and consequently this device draws much larger currents than it should for the work it is doing.

In conclusion, I think it might be well to mention the subject of safety. Millions of dollars are spent annually in promoting better working conditions and it is natural that electrical equipment should be evaluated from this standpoint. First of all, several organizations set up the standards of equipment and installation that insure low accident records. These are the Underwriters' Laboratories, the National Electrical Code, which is the standard of the National Board of Fire Underwriters, the State Electrical Code, which is administered by the Division of Industrial Safety, State of California, and the various city codes, such as Long Beach and Los Angeles. The state and cities are daily expanding their inspection departments for more thorough scrutiny of new installations. The requirements of these groups for explosion-proof joints (five full threads), explosion-proof fittings, approved sealing fittings wherever conduit terminates in enclosures where arcing or sparking is likely to occur, or where conduits leave a hazardous area, are all in the interest of maximum safety.

Most of you have noticed lately in all plants handling gasoline that electrical conduit runs are encased in red concrete to protect against accidental damage by work crews.

I have here some of the Division of Industrial Safety reports over the last few years, and reading over a few of them briefly will give us an idea of the natural gasoline plant accident trend.

Year 1939—Natural Gasoline Plant—One man fatally burned.

A chemist was loading butane in a truck with an electric pump. The switch box, situated outside the pump building, exploded when switch was thrown off.

Year 1941—Natural Gasoline Plant—One man fatally burned.

Explosion occurred in small gasoline pump house.

(b) Gas Compressor Plant—Three men injured, one fatally.

A corroded underground pipe failed upon being uncovered, gas spread to compressors and entered air intake of one of the compressor engines, it speeded up and both the compressor engine flywheel and the compressor flywheel broke. Ignition of gases, cause not known, but probably from sparks of bursting wheels, although other sources of ignition were probable.

(c) Oil Refinery—Eight men burned, three fatally.

While breaking into a liquid butane line that had not been drained and may have been open, a large volume of butane was released and the vapors ignited at compressor room.

(d) Oil Refinery—One man burned, nonfatal.

While washing an overhead condenser shell of a deisobutanizer, a 100-watt vapor-proof light globe cover and the light globe were cracked with water from a hose and broke, allowing glowing filament to ignite vapors.

These electrical accidents are strong points in favor of adhering to the codes and their explosion-proof requirements.

The successful use of motors within a hazardous area is not particularly a matter of motor design, but depends largely upon the careful attention to such factors as (1) selection and careful maintenance of proper types and sizes of overload relays; (2) proper lay-out of the distribution system, and (3) choice of breakers with adequate interrupting capacity.

Gentlemen, if you don't feel like you've had your work for a B.S. in E.E. you should, for here in brief form we have attempted to cover the essentials of applying electric power to the operation of a natural gasoline plant. ★ ★ ★

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Texas gas for California*

By **A. F. BRIDGE,** *Vice President and General Manager*
Southern Counties Gas Company of California

PART 2—*Conclusion*

This brings us to the next query—What are the optimum Mid-Continent sources for this market!

A survey of the known adequate reserves, within economic range of pipe line transportation, quickly narrowed down to the Hugoton-Panhandle fields and those of the so-called Permian Basin. Over a period of about two years we carried on a careful and comprehensive investigation of possible projects. We employed geologists to survey the reserves and prospective rates of availability for the producing areas mentioned. We conducted extensive map and field reconnaissance of possible routes. We designed and made estimates of capital and operating expenses for a number of tentative projects to transmit gas from Hugoton-Panhandle and from Permian Basin, both separately and in combination. We carried on extended negotiations with several producers who had leaseholds in these fields, and finally, last summer, entered into a contract with the El Paso Natural Gas Company to buy gas at the Colorado River obtained from both of these important sources. We are of course seeking a long-lived source, and experts who have made a most comprehensive investigation of these fields are satisfied that the reserves and contract rights supporting our project will insure meeting the draft requirements for a period of 30 years, which is the term of the contract.

The Hugoton and Panhandle dry gas fields, which cover parts of Texas, Oklahoma, and Kansas, together comprise the largest known gas reserve in the world, with estimated recoverable gas of approximately 40 trillion cu. ft., and a proved area exceeding 4,200,000 acres. Fig. 7, which I shall again refer to, shows the Permian Basin, in West Texas and New Mexico, a vast producing region spotted with many oil fields, the major portion of the gas being produced in conjunction with oil. For lack of a market nearly 400,000,000 cu. ft. per day of raw and residue oil-well gas is now wasting at wells and gasoline plants.

The market outlet that our pipe line will provide affords a means of utilizing large volumes of Permian Basin gas that otherwise would continue to be vented to the air, while the dry gas reserves and controllable deliverability of Hugoton-Panhandle will insure the supply continuity and long life that are vitally necessary to make a project of this magnitude feasible. The conservation of Permian Basin gas was one of the important factors which influenced the Federal Power Commission to act favorably upon our certificate application.

This brings us to consideration of the pipe line itself, which will convey this gas from well to customer. You are probably already somewhat familiar with the project from news stories, hence I shall not bore you with detailed specifications, but confine myself to a brief description, and touch on a few unusual design features. However, first a word on past technological developments that made it possible to design and build a pipe line such as this one.

Long-distance, high-pressure transmission of natural gas as we now know it, had its inception in 1927. The factor that made the industry as it now exists possible was the application in that year of new electric welding technique to the volume production of large diameter steel pipe. The greater diameters, higher stresses, and higher pressures that such pipe permitted, extended the economically feasible range of gas transmission from about 150 miles to the 1300 miles now employed.

Prior to that time there was available to the pipe line designer only lap-weld pipe, with approximately the following average physical properties for the finished tube: Net transverse strengths including seam-yield 28,000 lb. per sq. in.; ultimate tensile, 44,000 lb. per sq. in.; efficiency of longitudinal seam, 80 per cent.

With this product a designed working stress of about 12,000 lb. per sq. in. was considered good engineering practice.

★★★★★★

EDITOR'S NOTE: Since this paper was delivered contract for installation of the California portion of the pipe line was awarded by Southern California and Southern Counties Gas Companies to H. C. Price Company. The El Paso Natural Gas Company, which will build and operate the line from Texas to the California border, has contracted part of its section to Midwestern Engineers and will lay the rest with its own personnel.

The electric-welded pipe now available has the following properties:

	Average	Minimum
Transverse yield point, lb. per sq. in.	61,000	52,000
Transverse ultimate tensile strength, lb. per sq. in.	86,000	72,000
Seam efficiency, per cent		100

Thus, both the net yield and ultimate strengths have approximately doubled; but even more important, the dependability of the longitudinal weld has greatly improved.

Recently, large diameter thin-wall seamless pipe has been made available that almost matches the physical specifications and per-foot cost of electric weld pipe.

As a result of the foregoing changes in specifications, and based on experience gained in the use of pipe fabricated from plates by electric welding, the Code for Pressure Piping now permits a working stress in rural territory equal to 72 per cent of the specified or demonstrated yield strength. Under this code, stresses as high as 39,500 lb. per sq. in. have been employed, corresponding to a minimum specified yield strength of 55,000 lb. per sq. in. Thus, the working stresses customarily used in pipe line design have trebled in the last 20 years.

Concurrently, advances have been made in the design of gas-engine-driven compressors, thus reducing both capital and operating costs of such units.

Essential elements of a typical modern gas pipe line project comprise:

(1) Field collection systems in each tributary field.

(2) Field compressor stations in which the gas is processed for recovery of heavy fractions and the removal of hydrogen sulphide, if present, is dehydrated, and compressed to mainline pressure.

(3) The main pipe line.

(4) A series of mainline compressor stations situated at intervals of 60 to 200 miles.

The optimum compression ratio for present-day booster stations lies in the range of 1.3 - 1.8.

El Paso Natural Gas Company will build and operate that part of the project in Texas, New Mexico, and Arizona, and sell gas to Southern California Gas Company and Southern Counties Gas Company at Blythe. El Paso's pipe line design is based upon an ultimate maximum delivery of 305,000,000 cu. ft. per day. For the 737 miles between the Arizona-California border and the Eunice compressor station in New Mexico, 26-in. diameter pipe will be used, and the 251-mile extension, scheduled for the second year, from Eunice to Dumas in the Texas Panhandle, will be of 24-in. diameter. The compressor stations will have a total installed primary horsepower of 31,000, 45,000, and 130,000 respectively, for the three stages of development referred to later. Estimated cost of El Paso's part of the ultimate project is approximately $54,000,000.

The California companies' 214-mile connecting pipe line from the Arizona-

*Presented before the annual convention of the Pacific Coast Gas Association, San Francisco, California, September, 1946.

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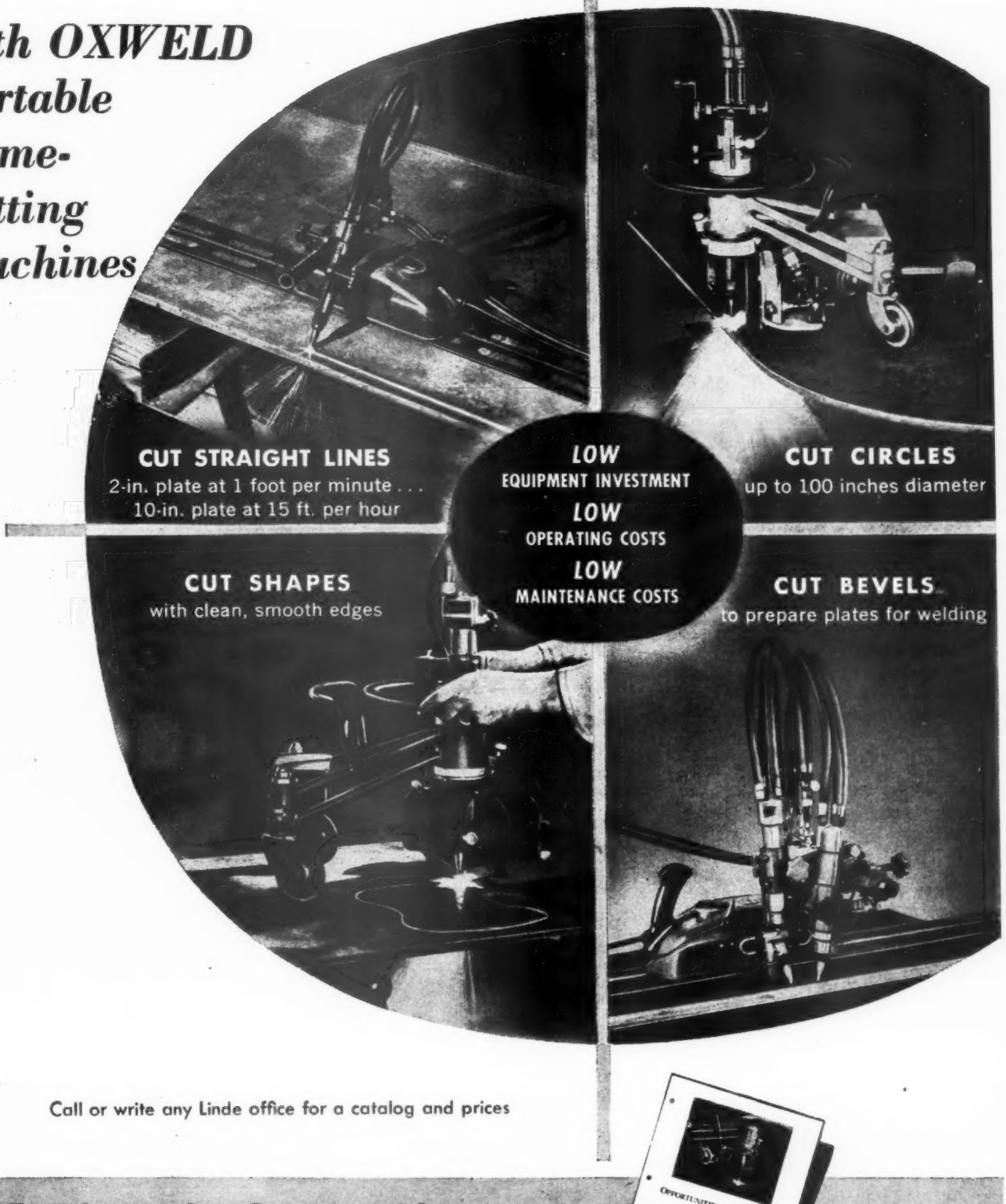

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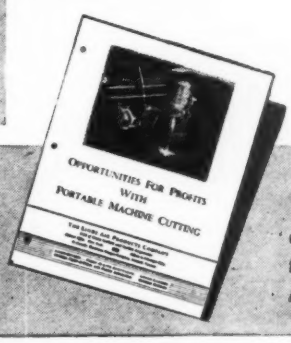

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California border to Santa Fe Springs will be 30 in. in diameter. A mainline compressor station of 10,000 hp. will be installed at Blythe, as well as pressure-limiting stations, lateral lines, and appurtenant facilities. The estimated capital cost of the California section at ultimate capacity is $16,225,000.

The total length of the main pipe line, consisting of 24-in., 26-in., and 30-in. pipe, from Dumas to Los Angeles, will be approximately 1212 miles, and the total project cost over $70,000,000.

The integrated pipe line project is planned for three progressive stages of capacity, with gas deliveries by the El Paso Natural Gas Company to the California companies at the Arizona-California border to begin in the fall of 1947, and to continue for 30 years. The contract requires the California companies to take gas at a minimum annual load factor of 91 per cent. The maximum contracted volumes to be delivered by El Paso are 125,000,000 cu. ft. per day the first year, 175,000,000 cu. ft. per day the second, third, and fourth years, and 305,000,000 cu. per day the fifth and succeeding years. Construction of the final stage is conditioned upon an election by the California companies prior to September 1, 1949.

Most of the design factors are common to both the El Paso company's section of the line and ours, hence a detailed description of each would be repetitious.

For the final stage El Paso will have six field stations and six booster stations, with an aggregate rated horsepower of 130,000. Total compressor fuel consumption, including our Blythe station, will be about 35,000,000 cu. ft. per day, or 10.4 per cent of input to field stations. El Paso's booster station spacing will average about 100 miles, compression ratios will range from 1.52 - 1.6, and pipe line operating pressures at station outlets will be 780 - 820 lb. per sq. in. Maximum design stress is 36,600 lb. per sq. in.

● **Design details—California section.** The designed working stresses for the California section of the line are 35,000 lb. per sq. in., in sparsely settled areas, and 25,000 lb. per sq. in. in populous territory and on or adjacent to roads and railroads, and, judged by present-day practice in the industry, they are conservative standards. These stresses may be compared with our specified minimum transverse strengths for the finished pipe (including the seam) as follows: Yield, 52,000 lb. per sq. in.; ultimate, 72,000 lb. per sq. in.

This part of the project has three unusual features. These are: (1) Its diameter—30 in. O.D.; (2) the use of pressure-limiting stations, and (3) a design that makes available approximately 52,000,000 cu. ft. of storage at relatively low cost.

Our original design called for 26 in. O. D. pipe, the largest that has been employed in other gas transmission lines, and the largest obtainable from Eastern pipe mills. Following negotiations, Consolidated Steel Corporation of Los Angeles undertook to manufacture 30 in. pipe to our specifications, and we awarded them a contract for some 60,000 tons. This job represents the first fabrication of large diameter, high-strength pipe on the Pacific Coast, and this manufacturer deserves commendation for pioneering in this field.

Among the features that led us to adopt 30 in. instead of 26 in. were:

(1) Reduction in required compressor horsepower, resulting in annual fuel savings of about $64,000, and increased net terminal delivery capacity.

(2) Possibility that capacity of the line might later be increased to 400,000,000 cu. ft. per day, in which case 30 in. would effect additional annual savings of $200,000.

(3) Following completion of this order, the local manufacturer will be in a favorable competitive position to supply any future orders for large-diameter, high strength pipe.

At the quoted pipe prices there was no significant difference in the overall initial capital cost of the project as between 26 in. and 30 in., since the higher unit cost of 30 in. pipe was offset by the saving in compressor horsepower.

● **Description of pipe fabricating process.** The pipe is being fabricated in a newly-installed production line in the Maywood plant of Consolidated Steel Corporation. The fabrication process is new to the West Coast in that it embodies continuous welding of the longitudinal seams and hydraulic expansion of the welded pipe sections.

The steps involved in processing the pipe from flat plate to finished section are shown in Fig. 8.

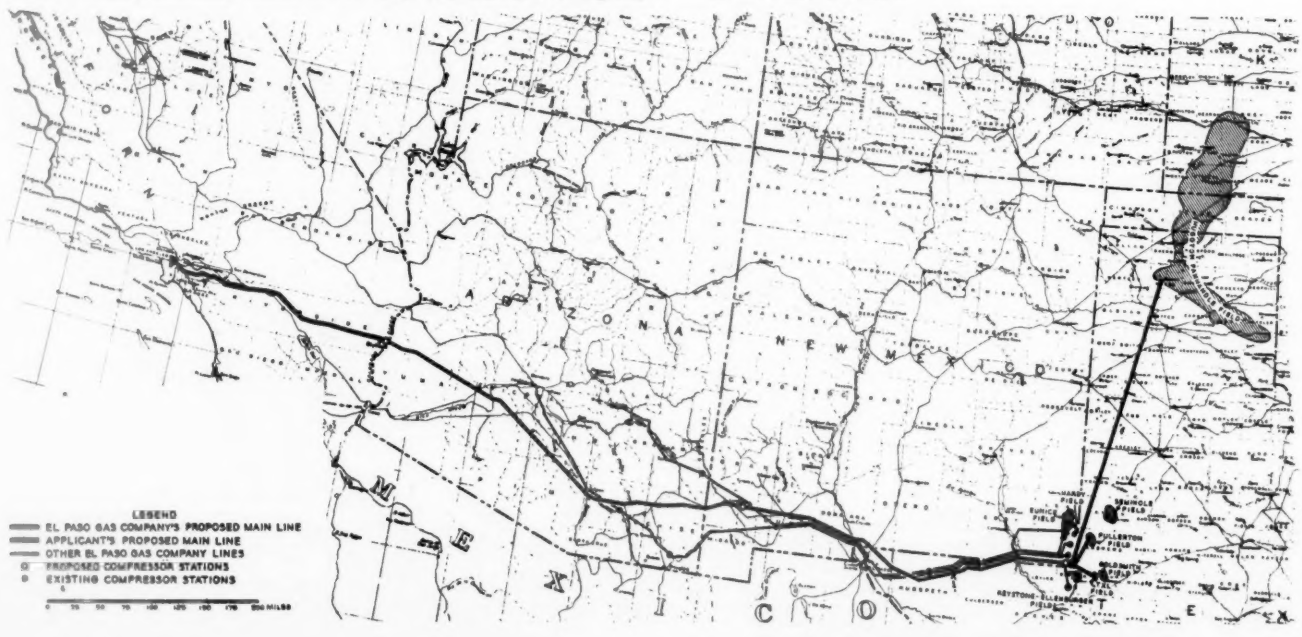
Plates of special manganese steel 30 ft. in length are passed on a conveyor through Leveling Rolls A, which remove any waves or buckles, Shear B, which trims the ends square and to proper length, and Grit-Blaster C, which removes mill scale from the edges to be welded, to Planers D, which reduce the plate to exact width and squareness and properly prepare both edges for welding.

The plates are then conveyed to the Edge Roll E, which forms both edges to the proper radius, and thence to one of two Pyramid Rolls F, in which the plates are rolled to cylindrical shape.

Upon leaving the roll, the cylinders are fed end to end through the Seam Welders G, in which the abutting edges are properly aligned and welded from the outside by submerged arc process.

In this process the edges are progressively fused together by means of heat generated by the passage of a heavy electric current between a bare welding electrode and the plate. The electrode is not in actual contact with the work, but the current is carried across the gap through a granular material, or "melt," which is laid down along the seam just ahead of

FIG. 7. Map showing route of El Paso Natural Gas Company's main line and feeders.



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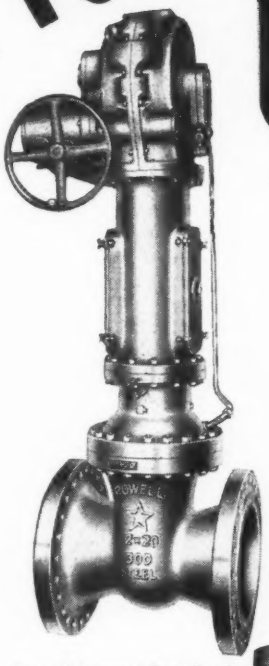

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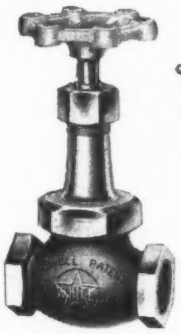

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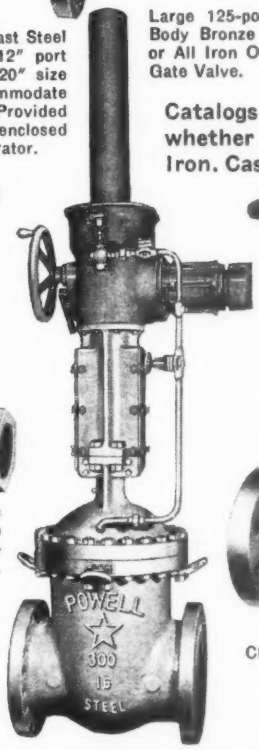

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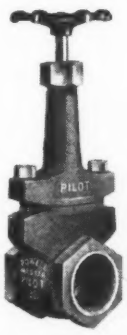

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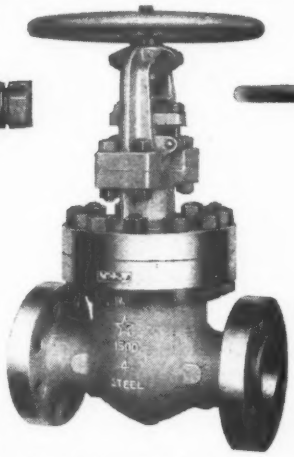
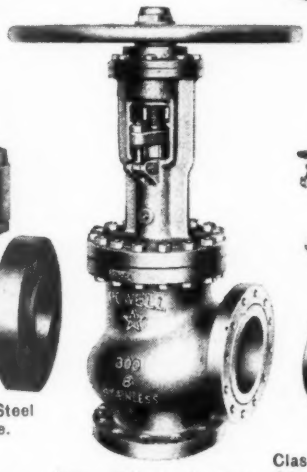
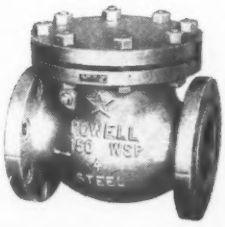


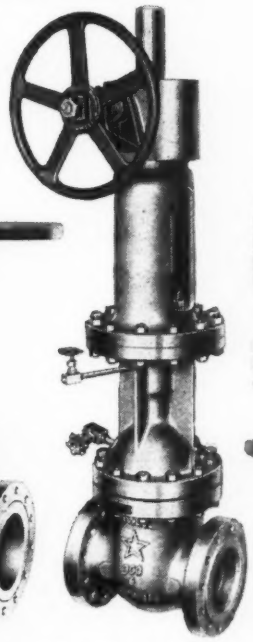
Class 1500-pound Cast Steel O. S. & Y. Gate Valve.



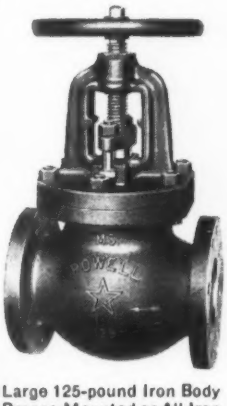
Class 300-pound Cast Alloy Steel O. S. & Y. streamlined Angle Valve. Adapted for high temperatures up to 1400 F.



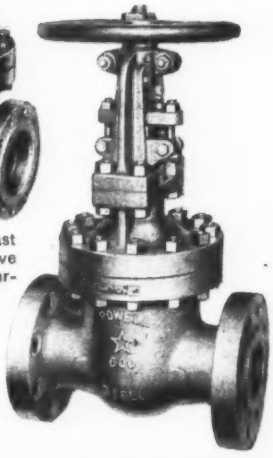
Class 150-pound Cast Steel Swing Check Valve.



Class 300-pound Cast Alloy Steel Gate Valve for ultra-high temperatures. Has cooling fins to reduce the temperature in the stuffing box.



Large 125-pound Iron Body Bronze Mounted or All Iron O. S. & Y. Globe Valve.



Class 600-pound Cast Steel O. S. & Y. Gate Valve.

POWELL VALVES

the electrode and in which the end of the electrode is submerged. The entire welding action takes place beneath the granular material without visible evidence such as flash, sparks, or spatter. The resulting weld is smooth in appearance, completely penetrates the plate, and possesses greater strength than the parent plate.

The cylinders at this stage are somewhat smaller in diameter than the finished outside dimension of the 30 in. pipe. In the next operation the ends of the cylinders are mechanically stretched in the End Expander H to 30 in. diam., after which they are rolled into one of the Hydraulic Expanders I. In this machine the pipe section, which is 30 in. diam. only at its ends, is placed between movable heads and surrounded by a cylindrical die of 30 in. inside diameter. The pipe section is filled with water, and sufficient pressure applied to stretch the pipe until it contacts the die.

The purposes of the expansion operation are several. First, the "cold working" of the steel materially increases its yield strength. Second, the expansion of the pipe into the cylindrical die produces uniform roundness and straightness. Third, the operation fully tests the strength of the welded seam at the yield strength of the parent plate.

After the pipe section is expanded, the internal pressure is reduced to a specified test pressure, the die is removed, and the weld is hammer tested and examined for leaks. Incidentally, the expansion of the pipe results in shortening of the 30-ft. section by several inches.

From the expanders the pipe sections are conveyed to the End Facer J and thence to the Circumferential Welders K, where two 30-ft. sections are welded together into a 60-ft. shipping section. The circumferential seam also is made by the submerged arc process.

The sections are then ready for coating and shipping to the job.

Throughout the process, from the making of the steel at the mills to the acceptance of the pipe for shipment, careful records, tests, and checks are made to insure the quality and uniformity of the product.

The weight of steel in the 214 miles of pipe is approximately 60,000 tons, and the scheduled production rate at the Maywood plant is nine miles per week, or about one 30-ft. section every 4¼ minutes.

Fig. 9 shows the pressure gradient along the California section under various conditions of flow. This illustrates and explains the other two design features previously mentioned—storage and pressure limitation.

For the final capacity stage (305,000,000 cu. ft.), shown by the upper pressure gradient, the maximum discharge pressure at the Blythe section will be 810 lb. per. sq. in., requiring a wall thickness of 11/32 in. for a 35,000 lb. per sq. in. stress. The closing of a valve at any point downstream from the compressor station, would subject the intervening section to this pressure, hence, if we did not employ pressure-limiting stations,

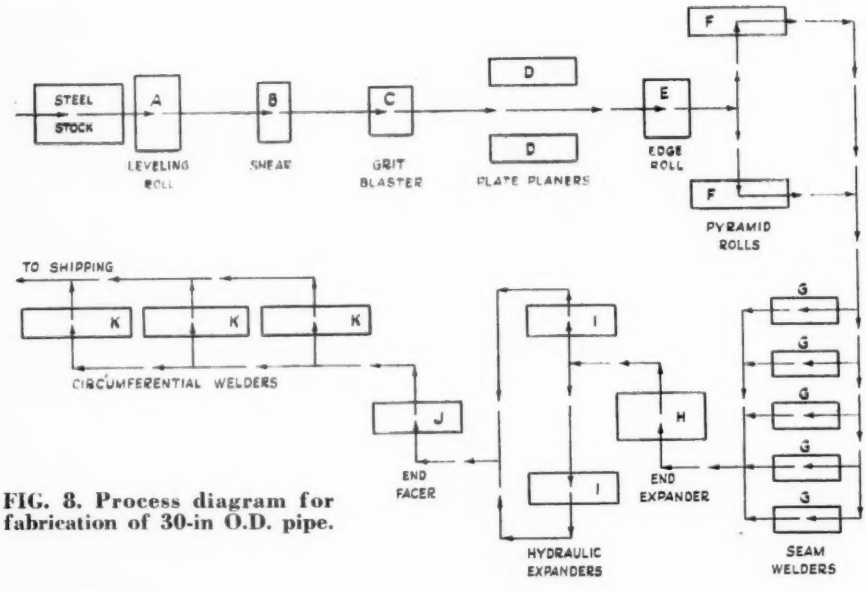


FIG. 8. Process diagram for fabrication of 30-in O.D. pipe.

the entire line would have to be 11/32 in. wall, except where it must be correspondingly heavier for those sections designed for 25,000 lb. per sq. in. stress.

By introducing three pressure limiting stations, we are enabled to graduate the wall thickness down to 9/32 in., thus saving some 7400 tons of steel, and about $600,000 in capital.

Each pressure-limiting station will be located at a mainline valve station, and will consist of several gas pressure-reducing regulators, operating in parallel in a bypass around the mainline valve. During periods of low flow, the main line valve in each station will close automatically, and all gas will pass through the regulators, which will limit the downstream pressure to the designed maximum. When the rate of flow increases beyond the combined capacity of the regulators, the mainline valves will open automatically. Relief valves will be installed at each station as secondary protection for the downstream section.

This graduated wall thickness design has been successfully employed by us since 1931 on several major lines, but to my knowledge has been neither publicized nor adopted elsewhere. Obviously, its employment should be limited to transmission lines where flow is certain to be unidirectional throughout the project life.

Mainline valve stations will be installed at about ten-mile intervals where the line is on private rights-of-way in desert country, and at shorter intervals where the line traverses populous territory. They will be welded into the pipe line, using 30-in. by 24-in. steel reducers, and each valve will be equipped with a piston-operated shut-off device to sectionalize the line automatically in the event of a rupture due to any cause.

Again referring to the pressure gradient chart, note the upper two lines. The lower of these shows the parabolic pressure curve corresponding to a uniform flow rate of 305,000,000 cu. ft. per day, requiring an initial pressure at Blythe of only 675 lb. per sq. in. to give a terminal pressure at Santa Fe Springs of 250 lb. per sq. in. By designing the line for the higher pressure corresponding to the upper line, and adding 2700 hp. in the Blythe station to compress gas to 810 instead of 675 lb. per sq. in., we obtain storage capacity, in the form of line pack, at relatively low incremental cost and with no impairment of the required 24-hr. deliverability of the line.

The area between the two 305 million curves indicates the potential volume of storage realizable under ideal conditions. The amount of storage that can actually be realized under operating conditions depends upon a number of factors, the most important being the hourly schedule of rates of flow from the line over the 24-hr. period of the operating cycle.

Maximum usable storage is attained when relatively high rates of withdrawal occur during the first few hours of the unpacking period and with very low rates of withdrawal during the last few hours of the packing period.

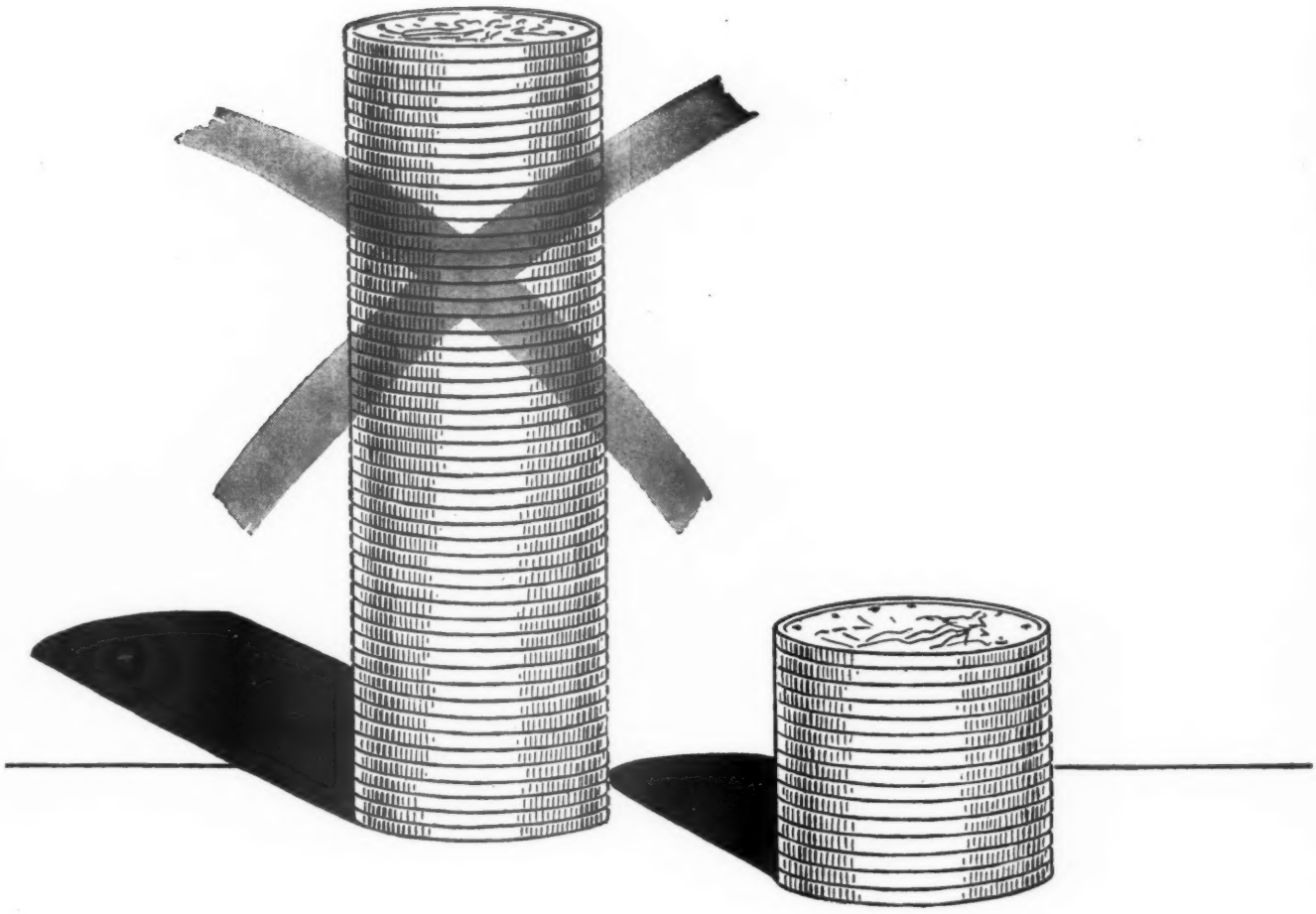
The realizable storage under planned operating conditions is estimated to exceed 52,000,000 cu. ft. This will be obtained at an added cost of $1,455,000, equivalent to $28.00 per 1000 cu. ft., or roughly one-sixth the unit cost of conventional gas storage holders,

During the unpacking period, gas can be withdrawn at a sustained rate of 500,000,000 cu. ft. per day for two hours, tapering off to the 305,000,000 cu. ft. average, the excess flow being compensated for by curtailing to a 100,000,000 per day rate during off-peak night hours.

The other specifications of the line follow conventional modern practice.

Internal corrosion will be prevented by dehydration by the El Paso company of the gas delivered to us at Blythe. External corrosion will be minimized by the use of a protective coating consisting of a coal-tar enamel—minimum thickness 3/32 in. and a wrapper of coal-tar impregnated 15-lb. asbestos felt.

Cathodic protection also will be applied to the entire pipe line to prevent corrosion that might otherwise occur at defects in the protective coating. The cathodic protection installation will con-



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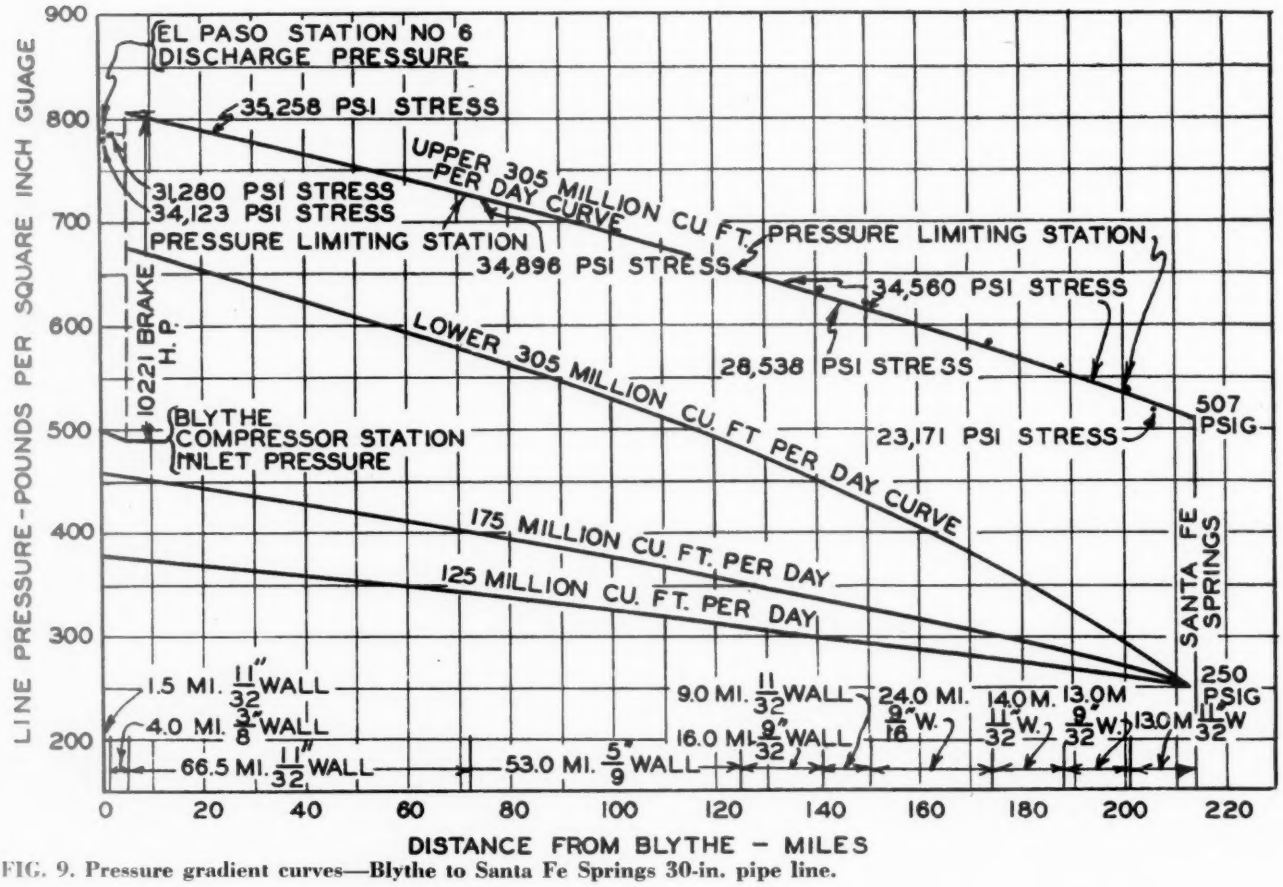

FIG. 9. Pressure gradient curves—Blythe to Santa Fe Springs 30-in. pipe line.

sist of eight electrical drainage stations, each one draining approximately 27 miles of line.

Bends will be made by inserting segments of weld ells, cut to fit the angular deflection and attached to the line by internal and external girth welds. It is expected that this type of construction will tend to improve the overall friction factor.

One paramount objective in designing a gas transmission line, particularly when, as in this case, it will supply a relatively large part of the total supply for an area, is continuity of operation. We must take all practicable precautions to insure against accidental interruptions of pipe-line flow, because to a gas man a service outage is unthinkable. This is by no means a matter of pride alone, but rather grim necessity. It is the avoidance of such a situation that causes us to expend many millions in capital to meet a heating peak demand that may occur only once in five to seven years.

Southern California has by far the highest saturation of automatic gas appliances of any comparable area in the nation. No successful method has yet been devised for rationing or curtailing the space heating consumption of our million-odd domestic and commercial customers, and hence we know of no sure way to prevent a supply deficiency in a given area from causing an outage.

River crossings constitute the most important potential source of service interruption in the territory traversed by this pipe line, and therefore they come in for a considerable amount of attention.

Among the larger streams crossed by the line are the Canadian, Pecos, Rio Grande, San Pedro, Gila, Colorado, and Santa Ana. Except for the Santa Ana, crossings of these rivers will be of the cable suspension type, similar in design and appearance to existing crossings of the Pecos and San Pedro. Span lengths between supports will range from 250 ft. for the Rio Grande to 1200 ft. for the Canadian. The Santa Cruz River crossing will be of the heavy-wall submerged type, and this design will also be employed for crossings of the Whitewater and San Gorgonio rivers, which are dry washes subject to sudden heavy flash floods.

So much for design. Now a statistic or two on the cost of gas delivered from this project, an item of paramount importance to our companies. The average cost of gas in the field, for the initial five-year period, is approximately 4 cents per 1000 cu. ft. of gas delivered at the Colorado River. This figure may be compared with total unit cost of gas delivered to the Santa Fe Springs terminus, being the sum of the contract price paid El Paso plus fixed and operating costs for the California section. For the three stages of development these overall costs are as follows:

125,000,000 cu. ft. per day capacity (first year), 20.3 cents per 1000 cu. ft.

175,000,000 cu. ft. per day capacity (second year) 18.1 cents per 1000 cu. ft.

305,000,000 cu. ft. per day capacity (1951), 16.5 cents per 1000 cu. ft.

These are based upon the obligatory minimum average load factor of 91 per cent.

Preliminary construction work on the El Paso company's line has been started. Grading of right-of-way, and trench excavation are under way in several mountainous sections where rock is encountered. Unavoidable delay in the delivery of electric weld pipe will be met by substitution of 228 miles of 26-in. seamless pipe of 0.303-in. wall thickness. Delivery of all compressor units is expected during 1946. The revised construction program calls for pipe line installation to begin early in January, 1947, and finish about October 1, 1947.

Bids have just been received covering the 214-mile California section and contracts will be awarded in the immediate future, with construction scheduled to start January 1, 1947, and job completion expected about September 1, 1947.

In conclusion may I sum up by the following comparisons the importance to California of successful consummation of this Mid-Continent project.

1. Its ultimate capacity of 305,000,000 cu. ft. per day is equivalent to about 66 per cent of the natural gas presently available to Southern California from all sources.

2. Total known California recoverable reserves of oil-well and dry gas are estimated at some 11.5 trillion cu. ft., of which about 9 trillion will be available to gas companies. During its expected minimum operative life of 30 years, the Texas line will enable us to import approximately 3 trillion cu. ft., thereby increasing by one-third our State's gas resources.

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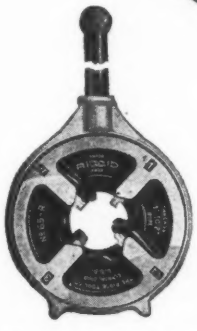

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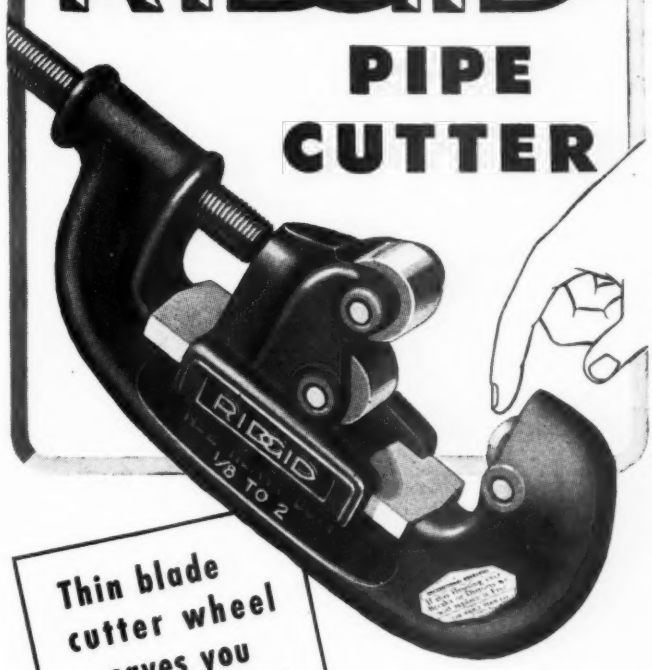

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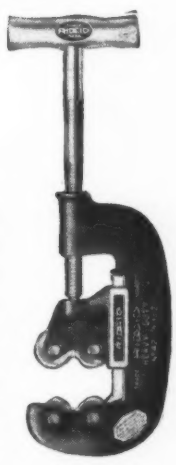

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Developments in centrifugal gas compressor field

By **H. M. SHEDD,** Carrier Corporation, Dallas, Texas

● **Introduction.** Information relative to developments in the field of centrifugal gas compression has not been very widely circulated. In fact, only in the past few years has any appreciable amount of real information been passed on to you in the gas industry. For this reason, perhaps the opinion exists that the centrifugal gas compressor is, in a manner of speaking, still wearing "three-cornered pants" and that a great deal still remains to be proved before it can have general acceptance in the oil and gas industry.

It will be my purpose to cover in a general way, some of the "high spots" relative to centrifugal gas compression.

● **History.** We might well begin this discussion with a brief history of the centrifugal gas compressor. Contrary to the popular belief, the compression of gas by means of centrifugal force has long since reached its maturity. In fact, the first installation of a centrifugal gas compressor was made a quarter of a century ago—and it is interesting to know that this original machine is still operating satisfactorily today. For those who are interested, this machine is installed in the Onandago Pottery Company, in Syracuse, New York.

As some of you may know, the first gas compressors were used in combination with appropriate heat exchangers for refrigeration service. My company has been building such machines since 1921.

In the first machines, dielene was the refrigerating medium; later on, as experience and knowledge was gained, gas compressors were developed that used a more satisfactory and efficient refrigerant—Carrene No. 1, or dichloromethane. The chemical formula of this refrigerant is CH_2Cl_2. Briefly, to bring us up to date in this connection, our centrifugal machines today employ a refrigerant known as Carrene No. 2 or Freon-11. The chemical formula is $CFCl_3$ and it was developed specifically for use in centrifugal machines, by Kinetic Chemicals Company.

This, then, is the background of the centrifugal gas compressor, a machine that was used in combination with heat exchangers, for refrigeration service.

The second chapter of the centrifugal gas compressor had its inception about six years ago, when the question was asked "Why not utilize the same principles for the compression of other gases —specifically, those hydrocarbon gases that are found in the gas industry?"

In this connection, you may be interested to know that the production of Carrene No. 1 and No. 2 begins with methane as a base, and ends up with one or more of the CH radicals replaced by chlorine or fluorine.

Thus the centrifugal compressor for natural and other hydrocarbon gases came into being. Fundamentally it is the same machine that has been performing refrigeration service for 25 years. There have been modifications, of course, such as the re-design of wheels and internal passages to fit the characteristics of the gas being pumped; also a new and stronger case was designed for the higher pressures encountered, and varied types of new seals were perfected.

● **Description.** We might now well ask: "What is a centrifugal compressor?" Right here, let me emphasize that it is not a rotary compressor. The rotary compressor is merely a positive displacement compressor with rotary instead of reciprocating pistons, and in most cases valves are required.

The centrifugal gas compressor is unbelievably simple. In appearance, it is similar to the centrifugal liquid pump with which you are all familiar. (See Fig. 1).

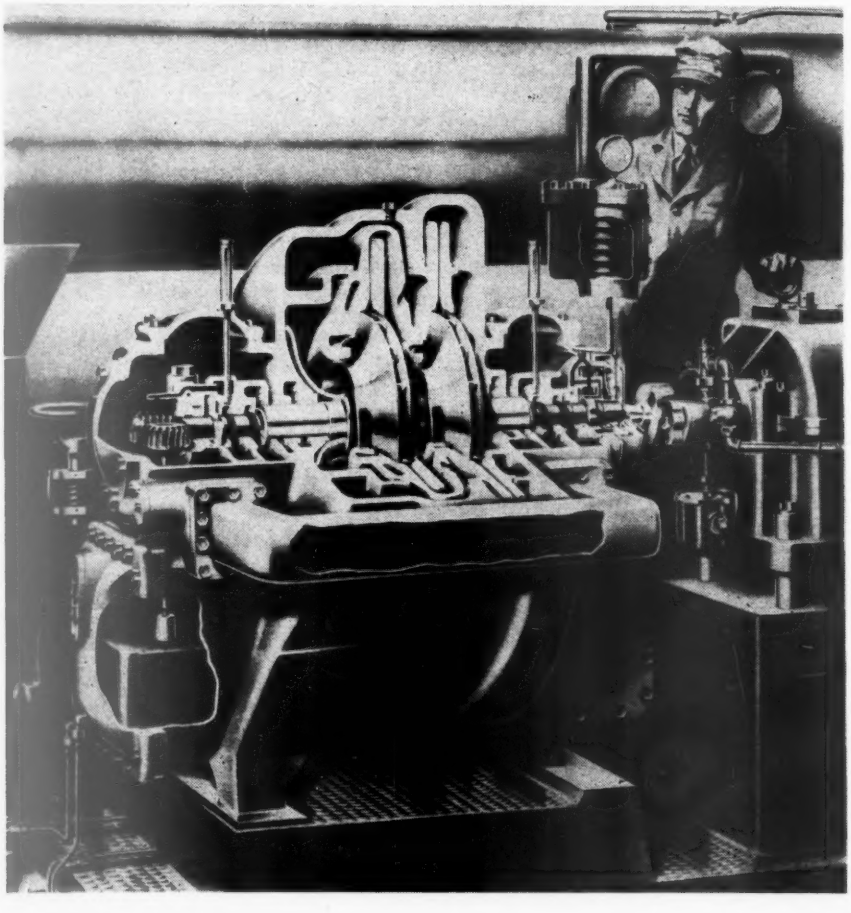
It consists, in general, of a short heavy shaft, to which are attached impellers or wheels. There may be anywhere from one to perhaps 11 or 12 wheels on this shaft. In Fig. 1 two are shown.

This shaft is carried in sleeve or journal type bearings and these bearings, in combination with a thrust bearing, are the only moving parts in actual contact. They are, therefore, the only parts subject to wear in the entire machine.

The stationary part of the machine consists of the external casing and diaphragms, which form the internal

*Presented at Short Course in Gas Technology, Texas A. & I. College, Kingsville, Texas.

FIG. 1. Centrifugal gas compressor.



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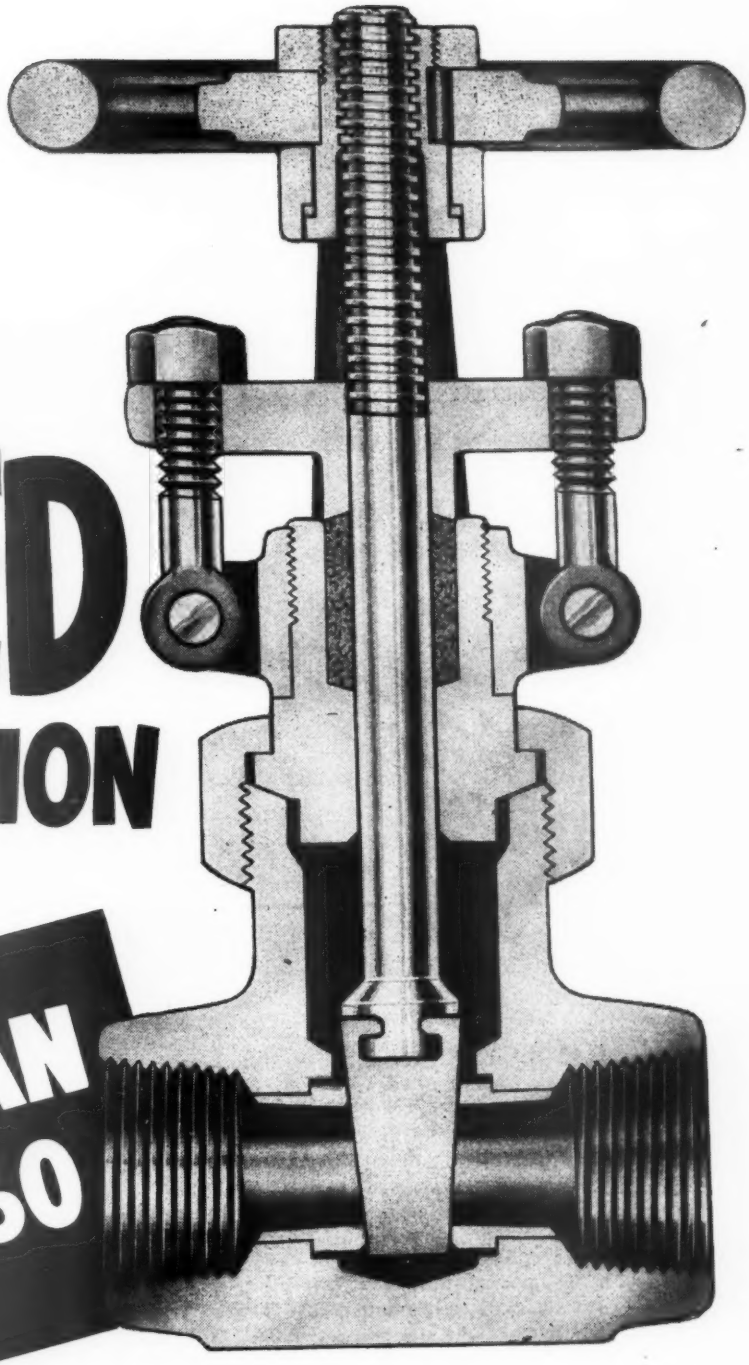

This fine small gate valve is built to perform perfectly in even the toughest services. It has a bonnet fitted with a substantial forged steel yoke and a flanged forged steel packing gland which eliminates exposed threading on the valve yoke, preventing rust and corrosion when the valve is used in exposed locations. Swivel bolts hold the packing gland—no gaskets to blow (as in valves with flanged bonnet connections)

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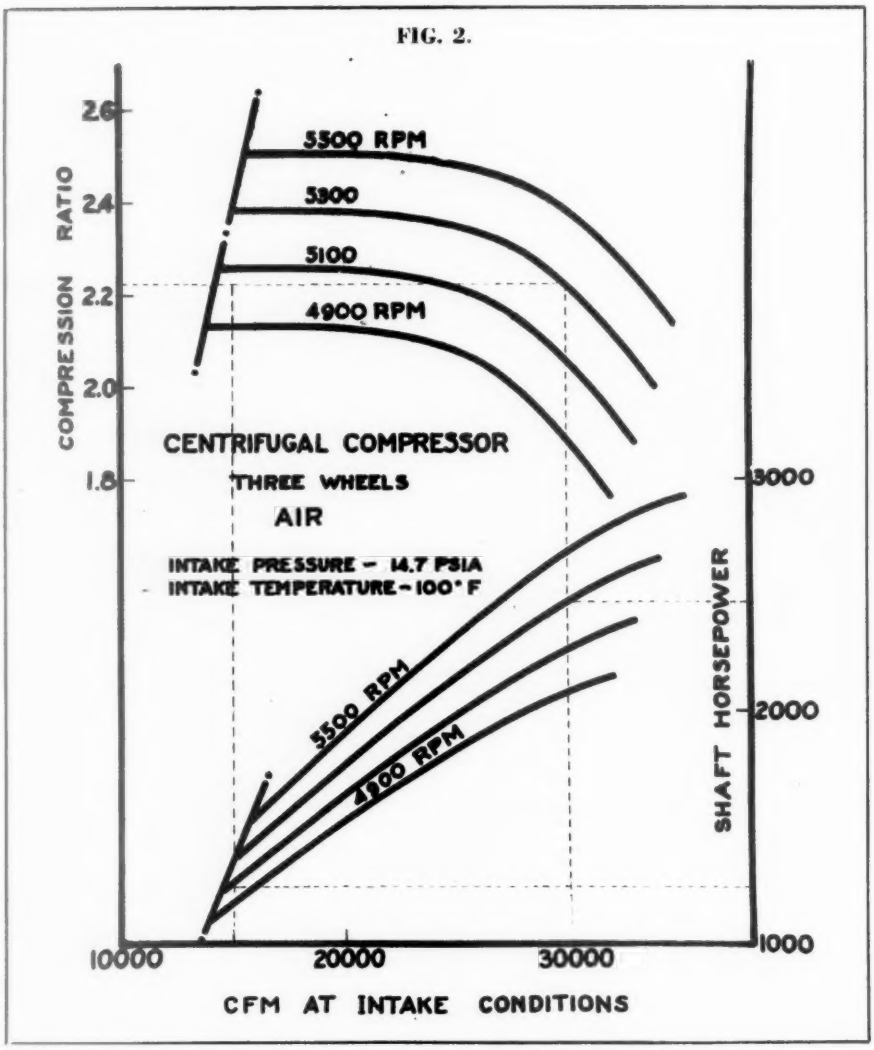
FIG. 2.



diffusers and return passages; certain auxiliary items such as the lubrication system, internal seals and a special shaft seal to prevent the leakage of gas or air complete the unit.

In design, the centrifugal gas compressor differs from the centrifugal liquid pump. This is due to the fact that the liquid pump handles a non-compressible fluid, whereas the gas compressor handles a fluid that varies not only in pressure, but also in temperature and volume throughout its journey through the machine. As the centrifugal handles a relatively light fluid its operating speed is usually considerably higher than that of centrifugal liquid pumps for comparable compression ratios. This comparatively high rotating speed provides the reason for the short heavy shaft, for this shaft is so designed that it does not pass through any critical speed in turning up to running speed.

● **Theory.** What is the theory in back of the operation of the centrifugal machine? It is not easy to describe this without resorting to technical terms. Mark Twain once described a "centrifugal fence." He said it consisted of an iron stake driven into the ground, with a rope tied to the stake, and a cow tied to the other end of the rope. If I had Mark Twain's genius perhaps I could describe a centrifugal force as easily.

In any event, I will not try your patience by referring to the "homely" analogy of the boy whirling a rock tied to the end of a string about his head, and then suddenly releasing the string. I have often wondered if the boy's father had to pay for a broken window.

Rather than become involved in a maze of uninteresting mathematical symbols and formulae, let me describe simply what happens to the gas as it passes through the machine.

In passing through the first rotating wheel or impeller, static and kinetic energy are imparted to the gas. After the gas leaves the wheel tip, it passes outward through a diffuser wherein the gas velocity is diminished, and part of the kinetic energy gain in the impeller is transformed into additional static energy, or pressure. The gas then passes through the return channel, and enters the second wheel and subsequently the second diffuser where this process is repeated and additional static pressure results.

● **Operating characteristics.** A great deal of time can be spent on the operating characteristics of the centrifugal compressor. Some of these characteristics can best be demonstrated by a set of typical performance curves. (Fig. 2).

These are curves taken from an actual installation. They are plotted: Intake volume in cu. ft. per min. measured at intake conditions vs. compression ratio, and vs. shaft horsepower. Each curve represents a given speed, specifically 5500, 5300, 5100, and 4900 r.p.m. This particular compressor is operating on air, entering at 14.7 lb. per sq. in. abs. and 100°F.

This point is the actual operating design condition, and corresponds to a volume of 30,000 cu. ft. per min. at a compression ratio of 2.225 at 5300 r.p.m.

Certain desirable features are obvious. As you will notice, a considerable variation in capacity at constant compression ratio is achieved by a small speed variation. A 50 per cent reduction in capacity is obtained by reducing the speed to 5050 r.p.m.—maintaining a constant compression ratio. In the case of the turbine drive, this speed change is readily effected by means of a variable speed oil relay governor actuated by the discharge pressure. You can well appreciate how advantageous such flexibility in pumping volume can be in the field, where the flow will vary from day to night, from day to day, and from year to year.

Now, what has happened to the horsepower. At 30,000 cu. ft. per min., or 100 per cent volume requirement, the shaft horsepower is 2470. At 15,000 cu. ft. per min., or 50 per cent volume, the power is only 1245 hp., or approximately 50.5 per cent of full load horsepower. Thus, it is evident that the power requirement is almost in direct proportion to the load demand.

Furthermore, there is great flexibility as regards variable suction pressures. In this same compressor, and without any internal or external modification, the compression ratio can be increased to overcome a reduced suction intake, simply by increasing the speed. Assuming the same 30,000 cu. ft. per min. intake volume is to be maintained, the compression ratio can be increased 2.225 to 2.38 simply by increasing the speed from 5300 r.p.m. to 5500 r.p.m.

There is additional flexibility in being able to handle gas streams of varying molecular weight. This is achieved, likewise, simply by speed variation.

Let us summarize:

1. The centrifugal offers a wide range of capacity variation.
2. Economical operation is obtained at partial loads.
3. There is flexibility as regards compression ratio and consequently varying intake pressure.
4. There is flexibility in handling a stream of varying specific gravity.

Perhaps some of you will be interested in some of the idiosyncracies of the centrifugal family. For example, why do we universally rate our machines in terms of so many "feet head"? Well, this is the reason: A centrifugal compressor, operating at a given speed, will produce a definite pumping head, expressed in feet, of the fluid being pumped, and it produces this same pumping head regardless of the gas being handled.

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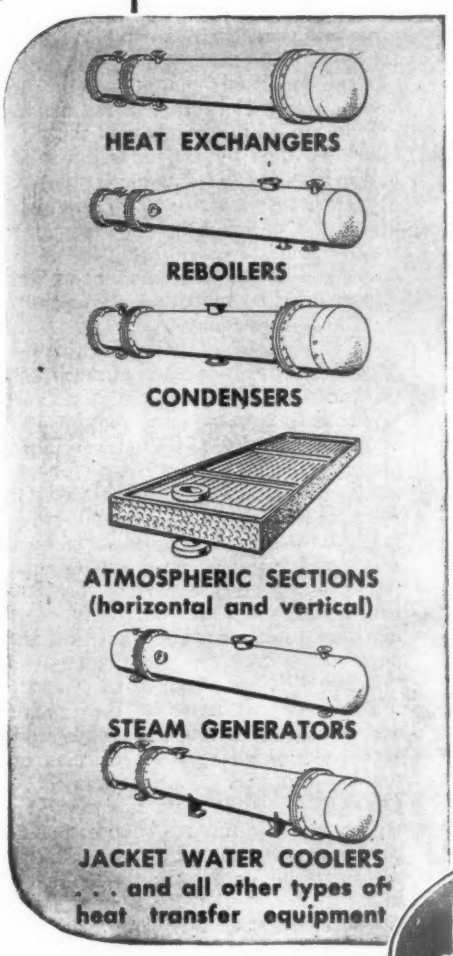

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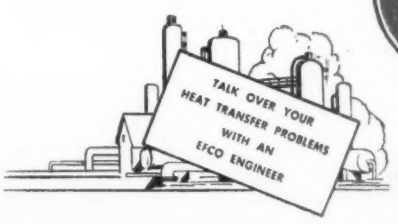

standing this if you visualize this pumping head as a column of gas extending vertically upward. Assuming we handle a heavy gas such as butane, this column is relatively heavy and exerts a relatively great pressure at the base. This is, of course, the pressure that the compressor must produce in order to support the column. On the other hand, if the compressor is handling natural gas, this column is relatively light in weight, and the pressure exerted at the base is relatively small.

This explains why a given 6-wheel compressor, operating at 9800 r.p.m. will deliver on the order of 14 compression ratios when handling butane, and approximately 3 compression ratios when handling average natural gas.

You people here are principally interested in natural gas—and three compression ratios isn't much, is it? If you want more, you simply pipe two or more machines in series, through gas intercoolers, and the compression ratio goes up, as the series: 3-9-27-and so on.

On the other hand, sometimes on booster service, three compression ratios is too much. Well, in this case, instead of a 6-wheel compressor, you substitute a 5, 4, or 3-wheel machine, and you obtain your final adjustment to the exact compression ratio requirement by means of a speed variation.

Fig. 3 illustrates what can be expected of compressors of three, four, and six wheels operating on various gases.

The compression ratio of a centrifugal is dependent upon the intake temperature, but is independent of the pressure.

Centrifugal compressors are available in a wide range of capacities. Machines are built that will handle up to 30,000 cu. ft. per min., measured at intake conditions of pressure and temperature, and more. I could phrase this in terms with which you are more familiar and say approximately 43,000,000 cu. ft. per day, measured at 14.4 lb. per sq. in., abs. and 60°F.; however, insofar as the centrifugal is concerned, what is important is the actual volume being handled regardless of the pressure and temperature.

Specifically, it might be said that a machine will handle 30,000 cu. ft. per min., at 100 lb. per sq. in. ga. intake pressure and give the same number of compression ratios, although the flow expressed in million cu. ft. per day is certainly much greater than if the compressor is operating at atmospheric intake. In fact, it is approximately eight times greater.

● **Limitations.** Let us admit that the centrifugal compressor has certain *limitations* and we want you to know just what those limitations are.

Inherently, the centrifugal gas compressor is a relatively large volume, large horsepower machine. In other words, it shows up to best advantage where there are relatively large volumes of gas to be pumped. Specifically, the centrifugal does not fit where gas volumes fall below 1200 to 1500 cu. ft. per min., measured at intake conditions of pressure and temperature.

Assuming these intake conditions are 14.4 lb. per sq. in. abs. and 60°F., this is equivalent to saying 1.75 to 2.15 million cu. ft. per day. If the intake pressure is 100 lb. per sq. in. ga., this means 13.9 to 17.1 million cu. ft. per day. On the other hand, if the intake pressure is a vacuum of say one-half atmosphere. this would be equivalent to 0.875 to 1.075 million cu. ft. per day.

The centrifugal is a large horsepower machine; it will take up to as high as 8500 hp. on a single shaft. From an economic standpoint, its lower limit might be set roughly at 200 hp. As the same external case and shaft is used for 4500 hp. as for 200 hp., the cost per horsepower is naturally reduced considerably on the higher horsepower applications. For large horsepowers, the compressor alone may range down to something less than $10.00 per hp.

Every problem, of course, has its own peculiarities, but, in general, I believe that centrifugals become generally competitive at about 300 to 400 hp.

Perhaps the greatest limitation to the universal use of the centrifugal machine has been the driver requirements. As of today, the ideal driver is the steam turbine. Developments were rapid in this field during the war, so that a number of companies have developed high-speed condensing turbines with extremely low steam rates. With these turbines, an 8 lb. to 10 lb. per hp. per hr. rate is obtained. What does this mean to you?

Well, it means that if you have a compressor requirement of say 1200 hp., you require only a 150 to 175-hp. boiler plant operated at 200 per cent rating.

This should considerably lessen the almost universal objection in your industry to steam power plants. We well appreciate your side of the picture: That many of your plants have only small amounts of water available, or that the water condition is bad, and we appreciate the problems involved in maintenance of a steam plant. But now, with these new high-speed, low-steam rate turbines, your problems have been minimized to a point where the objection will not be so great. In many plants, steam is required anyhow, and if the centrifugal is given an opportunity, especially on new plants, to show how it might fit into the heat balance, we feel that the centrifugal may well justify itself.

In lieu of steam turbine drive, electric motor drive may be offered. This type of drive, with step-up gear, is quite satisfactory—it does not offer the feature of direct connection and perfect control of volume or pressure.

● **Advantages.** You have seen how economies are effected at partial load operation, for example, 50.5 per cent hp. at 50 per cent load. You have also noted the fiexibility in capacity variation, and you appreciate the variable compression ratio and in handling streams of varying gas density, all without internal or external modification.

In addition, there are other features that should interest you.

As I previously mentioned, the only points of actual contact in the machine are the journal bearings, and the thrust bearings, thus the only possible points of wear are localized at these points. As a result, the centrifugal maintains its high level of efficiency throughout the years—10 or 15 years from now the machine will do the same amount of work, and require no more horsepower to do it, than it does today.

What are some of the other things you people look for in a piece of mechanical equipment?

The maintenance crew requires, first of all, a unit that will not continually have to be taken "off stream" for overhaul. The centrifugal machine is the solution. Odd as it may sound, we actually have some refrigeration compressors that have not been down for repair for as long as 10 years. However, if you fully appreciate the simplicity of the machine and recognize that the only parts that can wear are the bearings, this fact will not be too hard to accept.

Moreover, all parts of the machine are readily accessible—bearings for instance can be changed by one man in a few hours time. Furthermore, as the external case is split at the horizontal center line, all the "innards" can be reached simply by the removal of the top half of the case, which only weighs 3000 to 4000 lb.

The erection crew is intertested in a machine that can be easily handled, installed, and moved to a new location if desired later on. Furthermore, they are interested in minimizing the amount of piping and the amount of building that is required to house the equipment. Here again, the centrifugal compressor fits the picture. Insofar as the foundation requirements are concerned, only 6 to 8 cu. yd. of concrete are required. As

	3 WHEELS	4 WHEELS	6 WHEELS
AVG. NAT. GAS SP. GRAV. = .70	1.8	2.2	3.0
AIR	2.2	2.8	3.8
PROPANE	3.4	5.0	9.0
BUTANE	4.8	7.6	14.0

FIG. 3. Nominal compression ratios—100 per cent compressor revolutions per min.

not How?..

but *How Many?*

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the centrifugal is a precision built machine, with rotor statically and dynamically balanced, really the principal function that the foundation serves is to tie the motor or turbine and the compressor together.

On even the largest applications, whether from a volume standpoint, or from the power requirements, it is natural that a few centrifugal machines will do the job. Due to the relatively small number of machines for a particular application, the saving in interconnecting piping and valves is readily appreciated. As to housing requirements, well, if you want you can do without. I note that John Lynch of LaGloria Corporation is a member of the advisory committee of this "Short Course," and I believe that he will bear witness to the fact that he has two machines at Falfurrias sitting out in the open. But perhaps some of you aren't content unless you have a roof over your head. For those of you who are more demanding, you will be interested to know that the amount of "roof" required is reduced appreciably due to the small number of machines required, and to the small size of each machine, and that is important in the present housing shortage crisis.

● **Field of application.** Many of you will ask, "What is the field of application of this machine?"

The centrifugal gas compressor has a place in the field of straight gas compression, for example, in pipe-line transmission, in field gathering systems, in delivering absorber pressures in gasoline plants.

Further, these machines may be used in refrigeration systems, with propane, butane, isobutane, ethylene, and other common hydrocarbon refrigerants. In this field, machines have been used for lean oil chilling, deethanizer reflux condensing, propane dewaxing, and other similar applications.

Furthermore, this machine is also an air compressor, and as such has found use in catalytic cracking processes.

You will be interested to know that the centrifugal compressor played a major role in our wartime synthetic rubber and aviation gasoline programs. They fitted into the butadiene processes at the Cities Service plant in Lake Charles, the Firestone rubber plant at Lake Charles, in the Sinclair rubber plant, just out of Houston, in the Neches butane plant at Port Neches, and the B. F. Goodrich plant just across the road from Neches butane. Also in the butyl-rubber plant of Humble at Baytown.

● **Conclusion.** The history of the centrifugal compressor generally parallels that of the steam turbine—and just as a steam turbine has had universal acceptance in industry, I believe that as time goes on, more and more centrifugal gas compressors will take their place in service.

A modest beginning has been made and I personally know of 57,000 hp. that have been installed. It is our expectation that in the next few years this figure will be increased manyfold. ★★★

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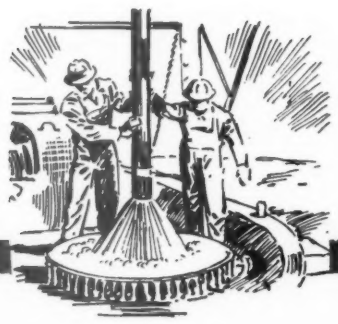

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Simplified pipe line computations

By **PEYTON BRYAN,** *Assistant Division Engineer,* Humble Pipe Line Company

PART 2

WE have found that the presence of f in the equations acts as a check-valve, permitting solutions to flow only from B toward h, and that life for the pipe-line engineer would be sweeter if f could be eliminated. Of course, this cannot be done in the general equations, but pipeline computations are never made for crude oil in general through pipe of indeterminate diameter. It is always the behavior of a particular liquid, with given characteristics of gravity and viscosity, that is investigated with respect to a given rate of flow or a given hydraulic gradient.

EXCLUSIVE

The field engineer will seldom have more than a dozen different grades of crude to contend with, and it is a simple job to devise for each grade a set of equations from which f will be very profitably absent. The process may cause some gnashing of teeth among hydraulic purists, but the resulting equations, of the form $h = a\,B^n$, are readily solved to the necessary precision with a log-log slide rule, and they provide a simplified approach to the complex problems to be considered later.

Considering the relationships of f and R, it is apparent that for a liquid of given viscosity, flowing through a pipe of given diameter, f is a function solely of B, and *for practical ranges of B in that pipe diameter,* $f = c\,B^m$. We are not going to consider 20 bbl. per hr. through a 12-in. pipe, nor pump 1000 bbl. per hr. through a 4-in.

For a given pipe diameter, equation (1) is of the form:

$$h = f\,e\,B^2 \text{ with } e = \frac{15.25}{d^5}$$

Substituting the value of f found in the preceding paragraph:

$h = (c\,B^m)\,(e\,B^2) = a\,B^n$ (with $a = c\,e$ and $n = 2m$).

Taking logarithms of each side of this equation:

$\log h = n \log B + \log a$

Now, let us assume a crude oil of 42 deg. API gravity, and 35 SUS viscosity. We require equations for 4-in., 6-in., and 8-in. pipe for field connections; 10-in. and 12-in. for main lines. Beginning with the 4-in. it will be necessary to take several values of B, covering a range from 75 to 300, and after solving equation (1) for the corresponding values of h, place the results in the logarithmic form shown above. If the reader's flow tables or curves have proved reliable, he can save time by taking these values directly from them, but the solution by logarithms gives a better understanding of the various relationships involved. As in any engineering computation, it will pay to be systematic.

35 SUS = 0.026 stokes kin. vis. $\quad d = 4.026$ in.

$$R = 22.14\,\frac{B}{dz} \qquad h = f\,\frac{15.25\,B^2}{d^5}$$

log 22.14		1.34518	log 15.25		1.18331
log 0.026		8.41497–10	5 log 4.026		–3.02435
log 4.026		0.60487	log $15.25/d^5$		8.15896 – 10
		9.01984–10			
log 22.14/dz		–9.01984–10			
		2.32534			

B = 75

log 75	1.87506	2 log 75		3.75012
log 22.14/dz	2.32534	log $15.25/d^5$		8.15896 – 10
log R	4.20040			
R	15,850			
f	0.0281	log 0.0281		8.44871 – 10
		log h		0.35779
		h		2.28′

B = 150

log 150	2.17609	2 log 150		4.35218
log 22.14/dz	2.32534	log $15.25/d^5$		8.15896 – 10
log R	4.50143			
R	31,730			
f	0.0235	log 0.0235		8.37107 – 10
		log h		0.88221
		h		7.62 ft.

Similar solutions for B = 225, and B = 300 show that:

B = 225	log 225 = 2.35218		
B = 300	log 300 = 2.47712		
log h = 1.8554	h = 15.33 ft.		
log h = 1.40987	h = 25.7 ft.		

Referring back to the logarithmic form of the equation $h = a\,B^n$, we write it out and place under each of its terms the values we have just found. If hydraulic data were more exact, it would be proper to solve the ensuing equation by "least squares," but for field pipe-line conditions a simple averaging gives as much precision as the data warrant.

(B)	log h =	n log B +	log a		
(75)	0.35779 =	1.87506 n +	log a		
(150)	0.88221 =	2.17609 n +	log a		
	2 | 1.24000 =	4.05115 n +	2 log a		
average	0.62000 =	2.02557 n +	log a	(1)	
(225)	1.18554 =	2.35217 n +	log a		
(300)	1.40987 =	2.47712 n +	log a		
	2 | 2.59541 =	4.82930 n +	2 log a		
average	1.29770 =	2.41465 n +	log a	(2	
	– 0.62000 =	2.02557 n +	log a	(1	
	0.67770 =	0.38908 n			
	n =	1.742			

Substituting this value of n in the averaged equations:

$\log a = -(2.90813)$

$$a = \frac{1}{809}$$

Then, for a crude of 35 SUS viscosity, through 4-in. pipe:

$$h = \frac{B^{1.74}}{809}$$

and $B = (809\,h)^{0.57} = 46.73\,h^{0.57}$

For the 6-in. line we might take values of h at 200, 300, 400, 500, 600, and 700 bbl. per hr.; average their respective logarithms in two sets of three each, and solve the resulting equations (1) and (2) by the same process as above. For the 8-in. line, we should take a range of from 400 to 1000 bbl. per hr.; for the 10-in., a range of from 1000 to 2000 bbl. per hr.; for the 12-in., a range of from 2800 bbl. per hr. Tabulating the results:

"X" crude
35 SUS viscosity 42 deg. API

4 in.	$h = \frac{B^{1.74}}{809}$	$B = 46.73\,h^{0.57}$
6 in.	$h = \frac{B^{1.78}}{7190}$	$B = 145\,h^{0.56}$

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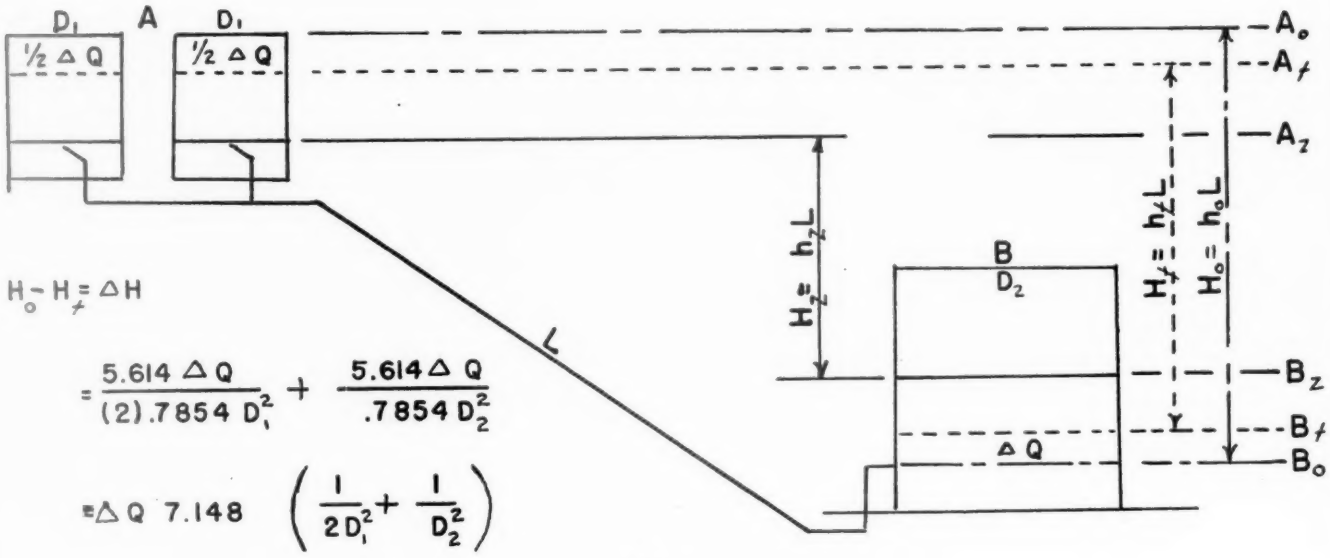

FIG. 1.

8 in. $h = \dfrac{B^{1.81}}{32{,}050}$ $B = 308.6\ h^{0.55}$

10 in. $h = \dfrac{B^{1.84}}{126{,}750}$ $B = 591.3\ h^{0.54}$

12 in. $h = \dfrac{B^{1.85}}{325{,}100}$ $B = 931.5\ h^{0.53}$

To express the hydraulic gradient in lbs. per sq. in. per mile, we multiply h by 5.28 (as h is in units of 1000 ft.), and, noting that 42-deg. API is equivalent to a specific gravity of 0.8155 and that a water column of 2.31 ft. produces a pressure of 1 lb. per sq. in., we divide h by 2.31/0.8155, or 2.83, which is the height, in ft., of the column of 42-deg. API crude giving a pressure of 1 lb. per sq. in. For example:

$$h_{4''} = \frac{B^{1.74}}{809.3} \qquad p = \frac{5.28\ h}{2.83}$$

$$p_{4''} = \frac{5.28\ B^{1.74}}{(2.83)\ (809.3)} = \frac{B^{1.74}}{424}$$

and $B = 32.65\ p_{4''}^{0.57}$

We won't take the space to put all "head in feet" equations into the "head in lb. per sq. in." form, but for your notebook you will find it convenient to do so. For each field whose oil you are running, you should have a record of the variations of viscosity and gravity with varying temperatures, especially the average "summer" and "winter" temperatures, and these data, with the appropriate equations such as those derived above, can be tabulated handily on a separate page of your field-book.

● **Application of equations to gravity lines and gravity systems.** In preceding discussions we have derived the general equations for pipe-line flow, and, finding the presence of the friction factor f an embarrassment, have seen that for a specific grade of crude, flowing through a given pipe diameter *within the practical range of flow rates for that diameter,* f is a function solely of the flow rate B and can be incorporated into the other constants, giving an equation of the form $h = a\ B^n$. This permits a direct solution for either hydraulic gradient h or flow rate B, by log-log slide-rule or two logarithmic operations, and provides an easier path to the solution of more complex problems.

Consider Fig. 1, which represents a battery of two lease tanks from which oil is to be gathered into the working, or storage, tank, (B). When the lease-tanks are "turned on," the oil level within theme is at elevation A_o, and the oil level in the storage tank is at elevation B_o, giving an initial "head" of H_o, When the battery is "turned off" at elevation A_z, there will have flowed through the line a quantity of oil, Q barrels, which will have raised the storage tank oil level to B_z, reducing the head to H_z. Practically, the problem is to determine how much time is required to "run" the two tanks of oil.

Assuming the two lease tanks to be of the same diameter, D ft., a flow of ΔQ in the interval of time Δt hours will lower their oil level by a height of $\frac{1}{2}\ \Delta Q\ (5.614)$ divided by the cross-sectional area of one of the tanks, while the oil level in the storage tank, whose diameter is D_2 ft., will rise a distance of $\Delta Q\ (5.614)$ divided by the cross-sectional area of that tank. Thus, the decrease in head ΔH is equal to the arithmetical sum of these two changes, or:

$$\Delta H = \Delta Q\ \frac{5.614}{0.7854}\left(\frac{1}{D_2^2} + \frac{1}{2\ D_1^2}\right)$$

$$= \Delta Q\ (7.148)\left(\frac{1}{2\ D_1^2} + \frac{1}{D_2^2}\right)$$

Let $(7.148)\left(\dfrac{1}{2\ D_1^2} + \dfrac{1}{D_2^2}\right) = c$

Then $\dfrac{dQ}{dH} = \dfrac{1}{c}$

By definition, B is the rate of change of Q with respect to time, or:

$$B = \frac{dQ}{dt} = a\ h^n = a\left(\frac{H}{L}\right)^n = \frac{a\ H^n}{L^n}$$

Let $\dfrac{a}{L^n} = b$

Then $\dfrac{dt}{dQ} = \dfrac{1}{b\ H^n}$

$$\frac{dt}{dH} = \frac{dt}{dQ}\frac{dQ}{dH} = \frac{1}{b\ H^n}\frac{1}{c} = \frac{1}{b\ c}\ H^{-n}$$

$$t = \frac{1}{b\ c}\int_{H_z}^{H_o} H^{-n}\ dH$$

$$= \frac{1}{b\ c}\ \frac{1}{(-n+1)}\ (H_o^{1-n} - H_z^{1-n})$$

For example, if D_1 is 21 ft.; D_2 is 40 ft.; the initial head H_o is 24 ft.; 14 ft. of oil is to run from each tank; then:

$$H_z = H_o - \left(14 + \frac{2(14 \times 0.7854 \times 21^2)}{0.7854 \times 40^2}\right)$$

$$= 2.3\ \text{ft.}$$

As we previously worked out equations for a crude of 42-deg. API and 35 SUS viscosity, we will suppose that to be the grade in the tanks. The pipe line is 4000 ft. of 4-in.

$$c = (7.148)\left(\frac{1}{2 \times 441} + \frac{1}{1600}\right) = \frac{1}{79.54}$$

For 4-in., $B = 46.73\left(\dfrac{H}{L}\right)^{0.57}$

and $\dfrac{1}{b} = \dfrac{4^{0.57}}{46.73} = \dfrac{2.2}{46.73}$

$$t = \frac{2.2}{46.73}\ (79.54)\ \frac{1}{0.43}$$

$$(24^{0.43} - 2.3^{0.43}) = 19.7\ \text{hr.}$$

Trying 6-in. for the line:

$$B = 145\left(\frac{H}{L}\right)^{0.56} \text{ and } \frac{1}{b} = \frac{4^{0.56}}{145}$$

$$= \frac{2.17}{145}$$

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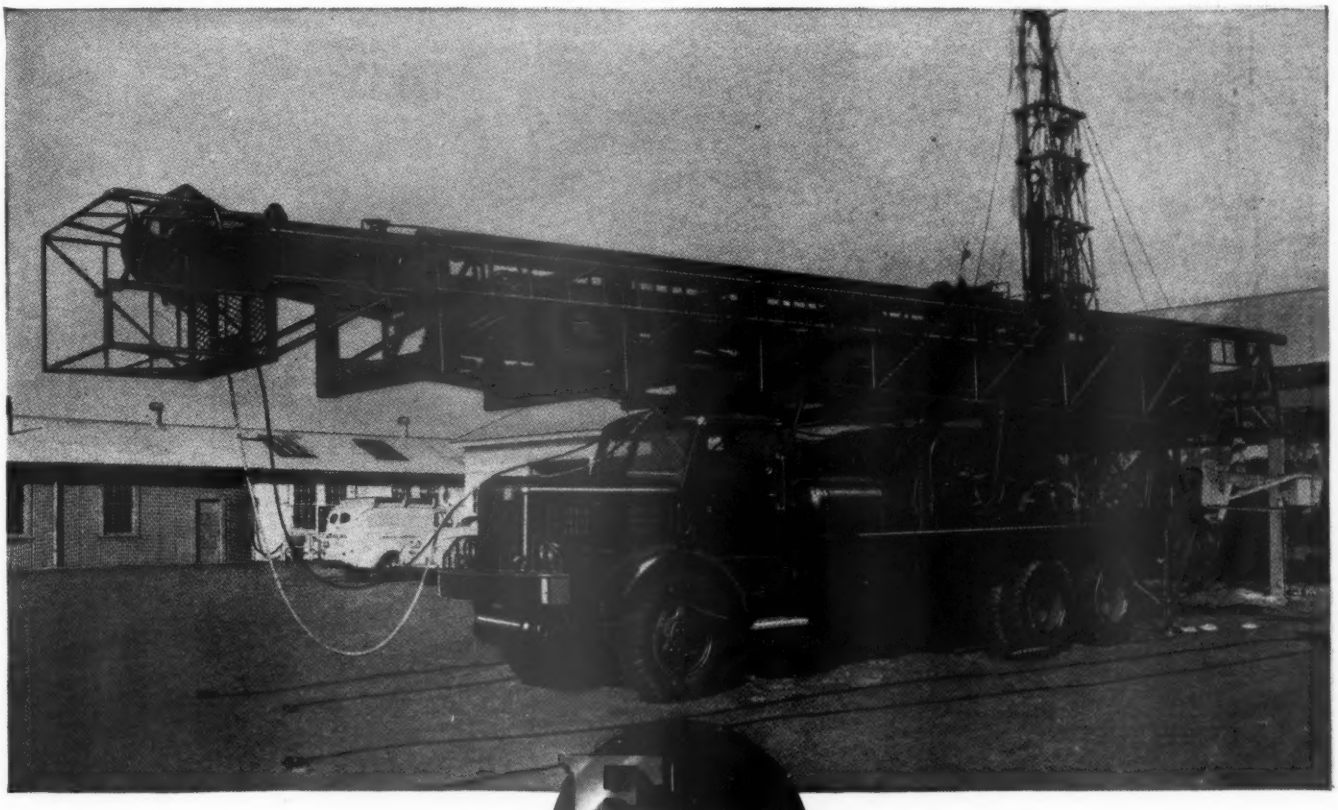

America's Foremost **FWD** *Heavy-Duty Trucks*

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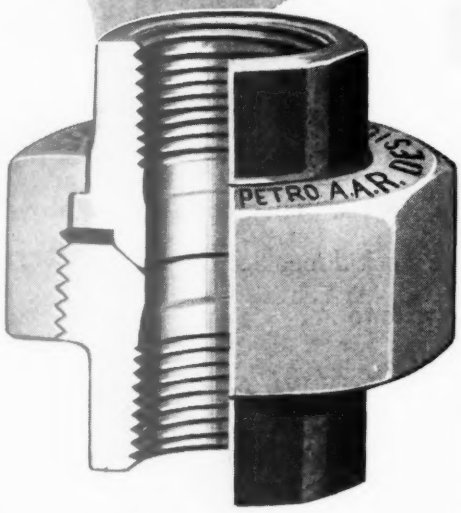
ENDURANCE

in FORGED STEEL UNIONS



SIZES ⅛" TO 3"

Petro

AMERICA'S MOST UNIVERSALLY USED UNION

PETRO unions have integral steel to steel seats. Made to A. A. R. design. 600 lbs. S.W.P.-2000 lbs. C.W.P. Extra heavy ends and nut with nut threads that are permanently lubricated. The seats are machined and cold rolled.

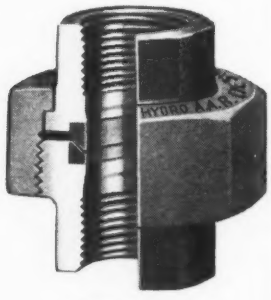
A PARTIAL LIST OF PROVEN SERVICES

Pressures from a vacuum to 3000 lbs.: Temperatures from 100° below zero F. to 1000° above zero F.: On Steam, Gas, Air, Oil, Gasoline, Ammonia, Chemicals, and any service in which Steel or Wrought Iron Pipe is Used.

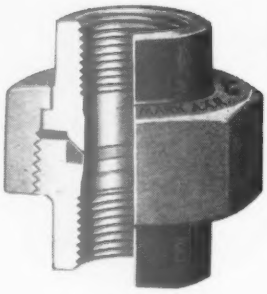
Hydro

THE ONLY FORGED STEEL UNION WITH TWO BRONZE SEATS

Made to A. A. R. design. 600 lbs. S.W.P.-2000 lbs. C.W.P. HYDRO unions have extra heavy ends and nut, with the nut threads permanently lubricated. The bronze seats are completely fused to the steel and are then machined and cold rolled.



SIZES ¼" TO 3"



SIZES ¼" TO 3"

Mark A.A.R.

AMERICA'S FIRST STEEL UNION

The MARK A. A. R. unions have bronze to steel seats. Made to A. A. R. specifications. 600 lbs. S.W.P.-2000 lbs. C.W.P. MARK A. A. R. unions have extra heavy ends and nut with the nut threads permanently lubricated. The bronze seat is completely fused to the steel and then machined and cold rolled.

WRITE FOR PAMPHLET AM-67 • ORDER BY TRADE NAME FROM YOUR JOBBER

ORIGINATORS AND PIONEERS OF FORGED STEEL UNIONS

CLAYTON MARK & COMPANY

1900 DEMPSTER STREET • EVANSTON, ILLINOIS

$$t = \frac{2.17}{145}(79.54)\frac{1}{0.44}$$

$$(24^{0.44} - 2.3^{0.44}) = 7.1 \text{ hr.}$$

The situation pictured in Fig. 1 would rarely occur in practice, as a pump is usually provided to take suction on the incoming gravity lines and discharge into the storage tank. In this case, ignoring any increase in rate of flow due to suction effect of the pump:

$$\Delta H = \Delta Q \frac{5.614}{0.7854}\frac{1}{2D_1^2} = \frac{7.148}{2D_1^2}$$

$$\text{and } c = \frac{7.148}{2D_1^2}$$

$H_z = H_o$ — (number of feet of oil to be run from each tank).

With a suction pump, then, the time required to run 14 ft. of oil from each of the tanks would be (for 4 in.):

$$t = \frac{2.2}{46.73}(123.4)\frac{1}{0.43}$$

$$(24^{0.43} - 10^{0.43}) = 16.6 \text{ hr.}$$

If 6-in. pipe is used:

$$t = \frac{2.17}{145}(123.4)\frac{1}{0.44}$$

$$(24^{0.44} - 10^{0.44}) = 5.4 \text{ hr.}$$

In many offices it is the custom, when figuring the flow of gravity lines, to ignore the "tank-head" and consider the effective head to be merely the difference in elevation between the lease tank outlet and ground at the suction pump. The excuse offered is that this method is on the side of safety, and that the line will assuredly have a better flow rate than the computations indicate.

The inaccuracy of such an approach is not fully reflected in the example given above. In the Gulf Coast fields there is often a gradient of no more than 1 ft. in 1 M ft. on gravity lines. Suppose a 21-ft. diam. tank whose outlet is 3 ft. above the elevation of the pump, to which it is connected by 3000 ft. of 6-in. pipe. If the oil is the same grade we have been considering, and the total head is taken as 3 ft., then:

$B = 145\left(\frac{H}{L}\right)^{0.56} = 145$, and the time required to run 14 ft. of oil, or 865 bbl., from the tank will be 6 hr.

Considered as an example of flow under a falling head:

$$c = \frac{7.148}{D^2} = \frac{7.148}{441}$$

$$\text{and } t = \frac{2.17}{145}(61.7)\frac{1}{.44}$$

$$(17^{0.44} - 3^{0.44}) = 3.9 \text{ hr.}$$

Actual timing of tank runs under these exact conditions has varied 0.2 of an hour from this value. Obviously, with low gradients and comparatively short lines, it is impossible to arrive at even a moderately accurate schedule of field runs by assuming the hydraulic gradient to begin at the tank connection.

In a future article, we will go into another widely practiced fallacy when we consider the multiple flow of two or more batteries as a gravity system. ★ ★

(The final part will be published in an early issue.)

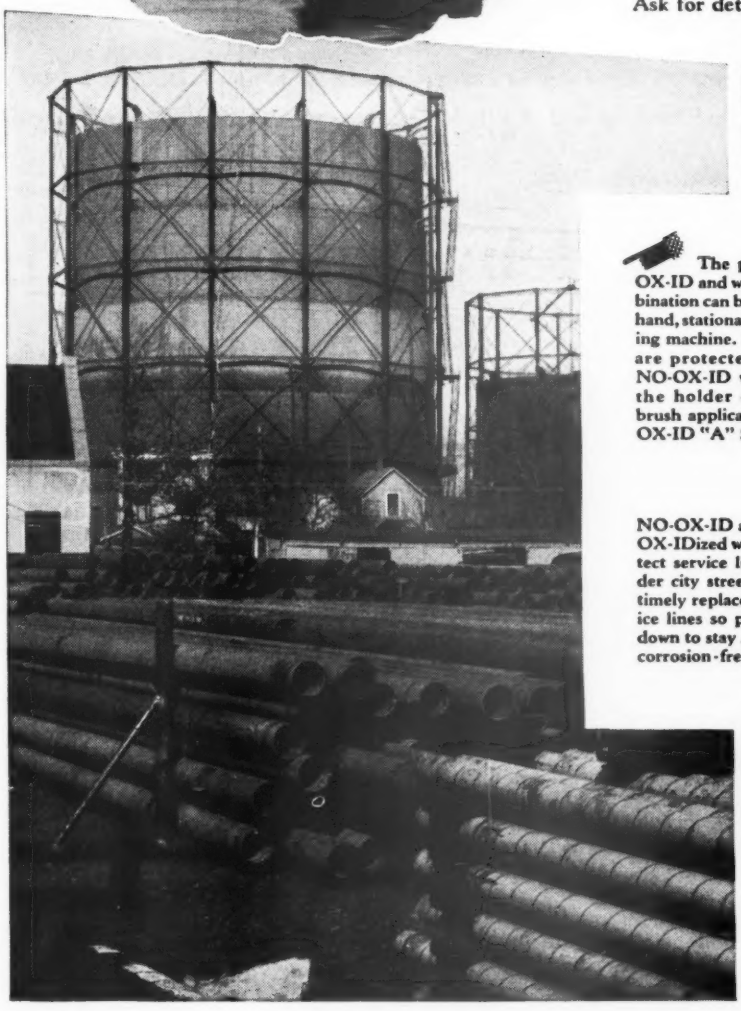
HOW TO PROTECT PIPE LINES AND TANKS AGAINST *CORROSION* is always a lively topic for discussion

Protection of tanks, and of pipe lines laid along river beds and through highly corrosive soils, was once a matter of deep concern.

Today, engineers dismiss their anxieties about corrosion and use NO-OX-ID, the *original* rust preventive.

NO-OX-ID coated pipe lines are given additional protection by NO-OX-IDized Wrapper, providing additional mechanical strength and increasing dielectric properties.

Ask for details about NO-OX-ID protection today. It lasts!



The proper NO-OX-ID and wrapper combination can be applied by hand, stationary, or traveling machine. Gas holders are protected by using NO-OX-ID water seal in the holder cups or by brush application of NO-OX-ID "A" Special X.

NO-OX-ID and NO-OX-IDized wrappers protect service lines laid under city streets from untimely replacement. Service lines so protected are down to stay . . . rust-and corrosion-free.

NO-OX-ID IRON OXIDE RUST
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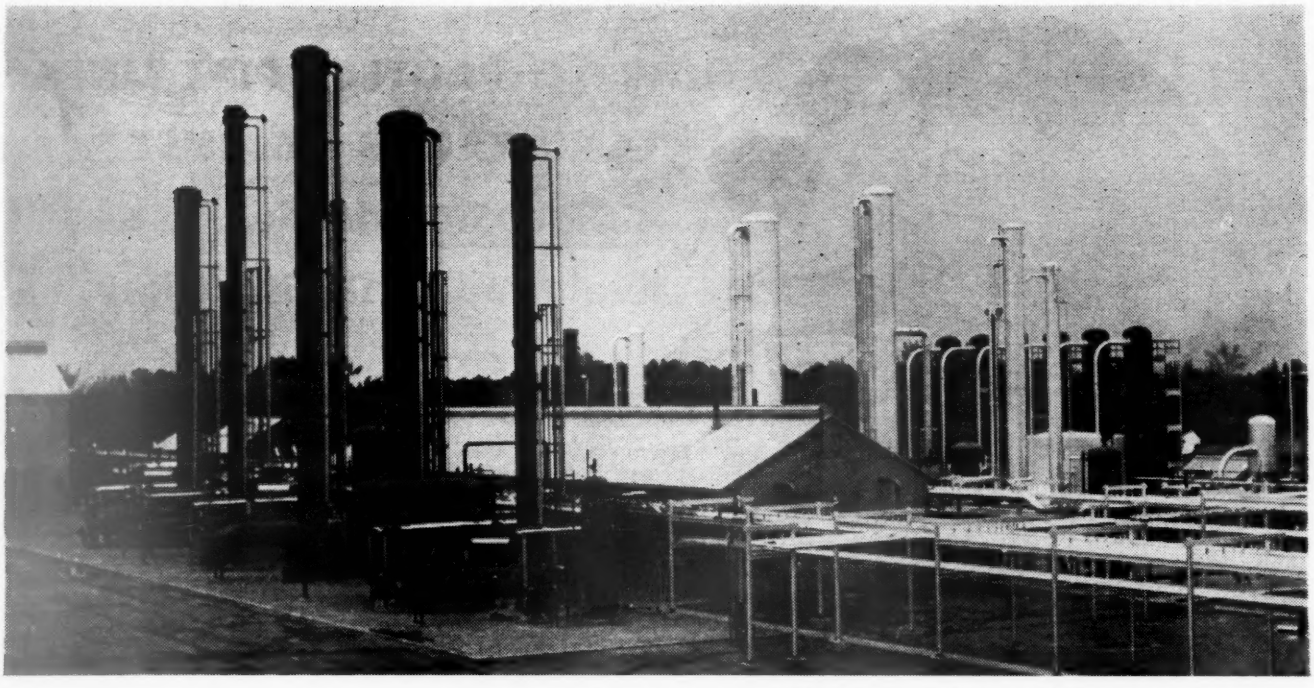

Fractionating and distillation equipment with pumphouse between.

Carthage gasoline and dehydration plant

By **FRANK H. LOVE,** *Managing Editor*

THE latest gasoline plant to be placed in operation in the Carthage field, Texas, is that of The Chicago Corporation and associates. This addition to the facilities of the vast gas field in the East Texas area, provides an outlet for 125,000,000 cu. ft. of gas a day, which is processed for recovery of its hydrocarbon content and the residue discharged into the system of the Tennessee Gas and Transmission Company, for commercial consumption.

EXCLUSIVE

The plant, situated three miles west of the town of Carthage, is designed for a minimum operating pressure of 1000 psi and a maximum pressure of 1250 psi. The plant actually consists of two units: (1) The gasoline plant proper, and (2) the dehydration plant.

The plant is of the absorption type, and in order to maintain high absorption efficiency a low molecular weight oil is required. A separate condensate system prevents the heavy ends of the distillate from contaminating the oil.

Upon entering the plant the gas is cooled and the pressure reduced from about 1800 psi to 1200 psi in a master separator. The liquid from this separator is flashed through a 575-lb. condensate vent tank, followed by a 250-lb. vent tank, and then passes through heat exchangers to the condensate still. Kerosine and lighter fractions are taken overhead in this still and are mixed with the feed to the primary still. The bottom product from the condensate still goes to an oil-purifying still. The overhead from the latter is absorption oil and goes either to storage or plant makeup. The bottom product is pumped to the heavy oil storage or slop tank. The oil-purifying still, in addition to producing absorption oil for the plant, is also used to recondition continuously oil from the main oil system. A small stream of oil is run continuously from the main still into the oil-purifying still.

The main gas stream, after passing through the master separator, then passes through the three high-pressure absorbers, which are connected in parallel. The rich oil from the high-pressure absorbers is first pumped through a 570-lb. vent tank and then through a 250-lb. vent tank. Vapors from each of these vent tanks is treated in separate reabsorbers. The oil then goes through conventional type heat exchangers to a primary still, which is operated at a pressure of 215 psi. A rough cut is taken in this still, the principal object being to remove the ethane. The overhead goes direct to the deethanizer where the ethane is taken overhead, the bottom product being propane and heavier.

The oil from the base of the primary still goes through a direct-fired fat oil heater to the main still. In this still, kerosine and lighter fractions are taken overhead. Absorption oil is pumped from the base of the main still through heat exchangers and coolers and back over the absorbers.

Overhead from the main still goes direct to a fractionator where gasoline is taken overhead. The end point of the gasoline can be controlled from 250 to 400°F. The bottom product, consisting of naphtha and kerosine, goes to the kerosine fractionator where the proper separation is made. The gasoline, which is taken overhead from the fractionator, is combined with the bottom product from the deethanizer and this mixture passes to the debutanizer. Finished debutanized gasoline is taken from the bottom of this tower to storage and the overhead goes to the depropanizer, where propane is separated from the mixed butanes.

Storage tanks are provided for propane, butane, liquefied petroleum gas, gasoline, naphtha, kerosine, absorption and fuel oil, the total storage capacity being 174,192.08 bbl. For the various products, this tankage is divided as follows: Butane, 20,189.76 bbl.; gasoline, 85,369.24 bbl.; kerosine or distillate, 30,190.57 bbl.; gasoline or naphtha, 30,176.17 bbl.; fuel oil, 4,186.66 bbl.; absorption oil, 2,095.65 bbl.; propane, 1,385.55 bbl., and liquefied petroleum gas, 598.48 bbl.

An Ethyl blending plant has been pro-

WeldELLS

for example:

selective reinforcement

The bursting stresses in an elbow subjected to internal pressure are known to be greatest at the crotch or inner arc. Mathematical calculations (see formula below) show how much greater the stress is in this region of an elbow, and the calculations have been closely confirmed by experiments.

This is taken into consideration in forming WeldELLS. As shown in the sectional illustration, extra wall thickness is provided at the inner arc to offset the added stress imposed.

There is no better evidence than this of the extra lengths we have gone to in engineering WeldELLS for full strength throughout. But there are plenty of other evidences of extra operations—extra value—that are yours only in WeldELLS and other Taylor Forge fittings for pipe welding.

A number of these extra value features are listed opposite. Combined only in the fittings that "have everything", these features mean greater soundness, speed and economy when your pipe welding is done the WeldELL way.

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WeldELLS alone combine these features:

- **Seamless**—greater strength and uniformity.
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- **Precision quarter-marked ends**—simplify layout and help insure accuracy.
- **Selective reinforcement** — provides uniform strength.
- **Permanent and complete identification marking**—saves time and eliminates errors in shop and field.
- **Wall thickness never less than specification minimum**—assures full strength and long life.
- **Machine tool beveled ends**—provides best welding surface and accurate bevel and land.
- **The most complete line of Welding Fittings and Forged Steel Flanges in the World**—insures complete service and undivided responsibility.

have everything

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vided to lead the motor fuel to the proper octane rating.

Shipments are made from a 24-car loading rack and a truck loading rack.

● **Gas dehydration.** After leaving the main oil absorbers, the stripped gas passes through a separator and enters the Florite contactors of the dehydration plant, which are 66 in. in diam. and 32½ ft. high. The plant has six contactors, three being on stream while the remaining three are being regenerated. The contactors are regenerated under full line pressure. A small amount of gas is heated by a steam exchanger to approximately 400°F. and passed through the three saturated contactors. The hot wet gas is cooled in the cooling tower, the water removed in a separator, and the gas returned to the inlet of the contactors. After regeneration, the contactors are cooled and are ready to be placed back on stream. A dew point of minus 25°F. or lower is being maintained.

● **Manufactured products.** The plant will produce daily approximately 300 bbl. of propane, 500 bbl. of butane, 2000 bbl. of 400-end point gasoline, and 200 bbl. of kerosine.

● **Steam systems.** The plant has three steam systems: One at 300 lb., one at 125 lb., and a 15-lb. system. The 300-lb. steam is used for agitation in the primary still and in the condensate still, and also to drive the turbine-driven pumps. These turbines exhaust into the 125-lb. system. The 125-lb. steam is used in the various reboilers and reciprocating pumps. The reciprocating pumps discharge into the 15-lb. system, which is used for agitation in the main still and oil-purifying still. Condensate from the reboilers is returned to the boiler feed water tank.

Condensed steam from the stills and accumulators is clarified in a Permutit system and the water returned to the boiler feed water tank. As the steam used in the various turbines and reciprocating pumps is well balanced with the agitation steam, the remaining pumps necessary to operate the plant are motor-driven centrifugal units.

Makeup water for the boilers is produced in an evaporator. The raw makeup water is passed through a deaerating heater to the evaporator where the water is treated chemically. In the tubes 300-lb. steam is used, and the makeup water is evaporated in the shell and passes into the 125-lb. system. The water in the cooling tower is chemically treated for scale control, as well as chlorinated for elimination of algae.

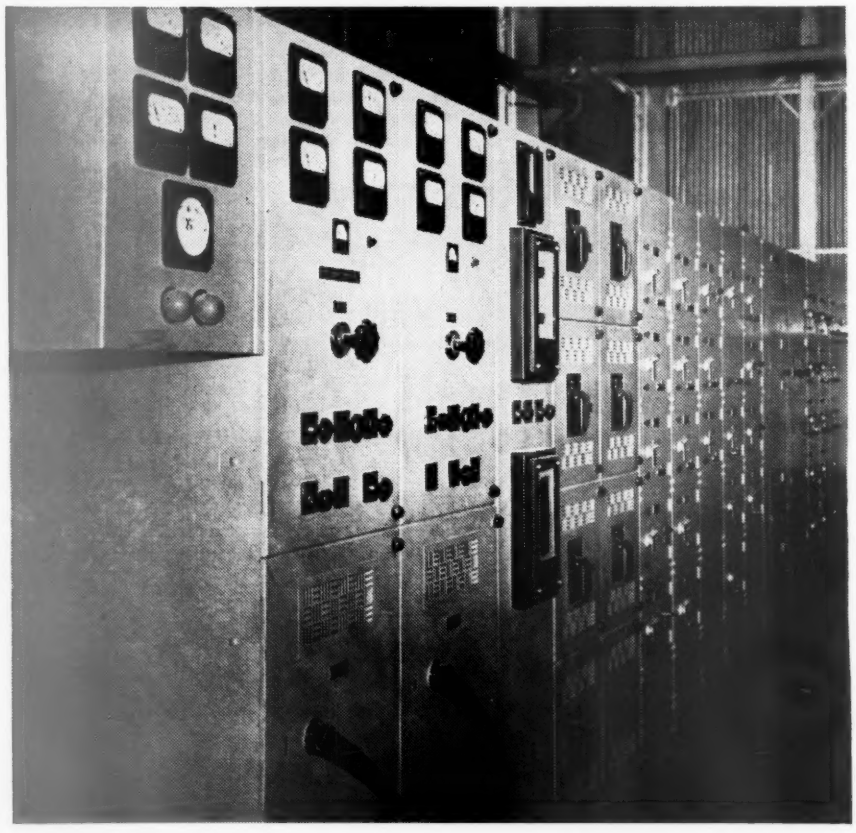
Steam is generated in the three water-tube boilers, each of which has a capacity of 30,000 lb. of steam an hour at 300-lb. pressure and 500°F. total temperature. Induced draft is used on the boilers.

● **Other auxiliary equipment.** The laboratory is equipped with standard distillation equipment, Podbielniak fractional analysis apparatus, and octane testing machines.

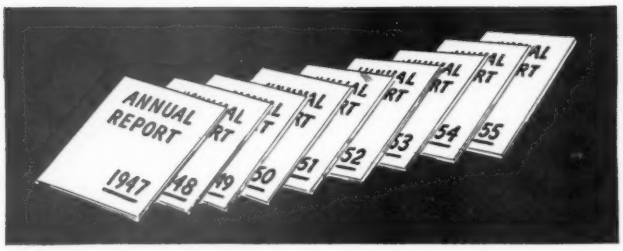
All cooling in the plant is accomplished through open bent tube sections placed in the bottom of the induced-draft, double-flow tower, which has a capacity of 14,000 gpm. Makeup water for the cooling tower is supplied by two 300-ft. deep gravel-packed wells that can produce 300 gpm each.

Direct-fired heaters are used to heat the rich oil to the main still, to heat the

Main generator control board and distillation area load center.



WHERE THE MOST IMPORTANT THING IS EVERYTHING!



"There Can Be No Substitute for the Best Design!"

Many factors influence ultimate earning power of a refinery. But nothing provides a sounder base for favorable statements . . . than proper design of refining facilities.

For example, *quality as well as quantity of yield* are established for years to come on the drawing board.

Direct operating costs, primarily a function of fuel costs, can be reduced to a minimum only when use of utilities is correct in design conception.

Stream efficiency stems directly from the efforts of the process and mechanical engineers.

And *maintenance,* while controlled by operation, can still be favorably affected by intelligent specification of metallurgical and equipment standards.

Finally, *flexibility*—the ability to follow the supply of raw materials *and* the market for products—must be designed into a refinery unit *before* its construction.

These are not by any means all of the "plus values" that design can contribute to earning power. However, they do point inexorably to the conclusion that . . . for earning power to be at the maximum during the life of processing units . . . "There can be no substitute for the *best* design!"

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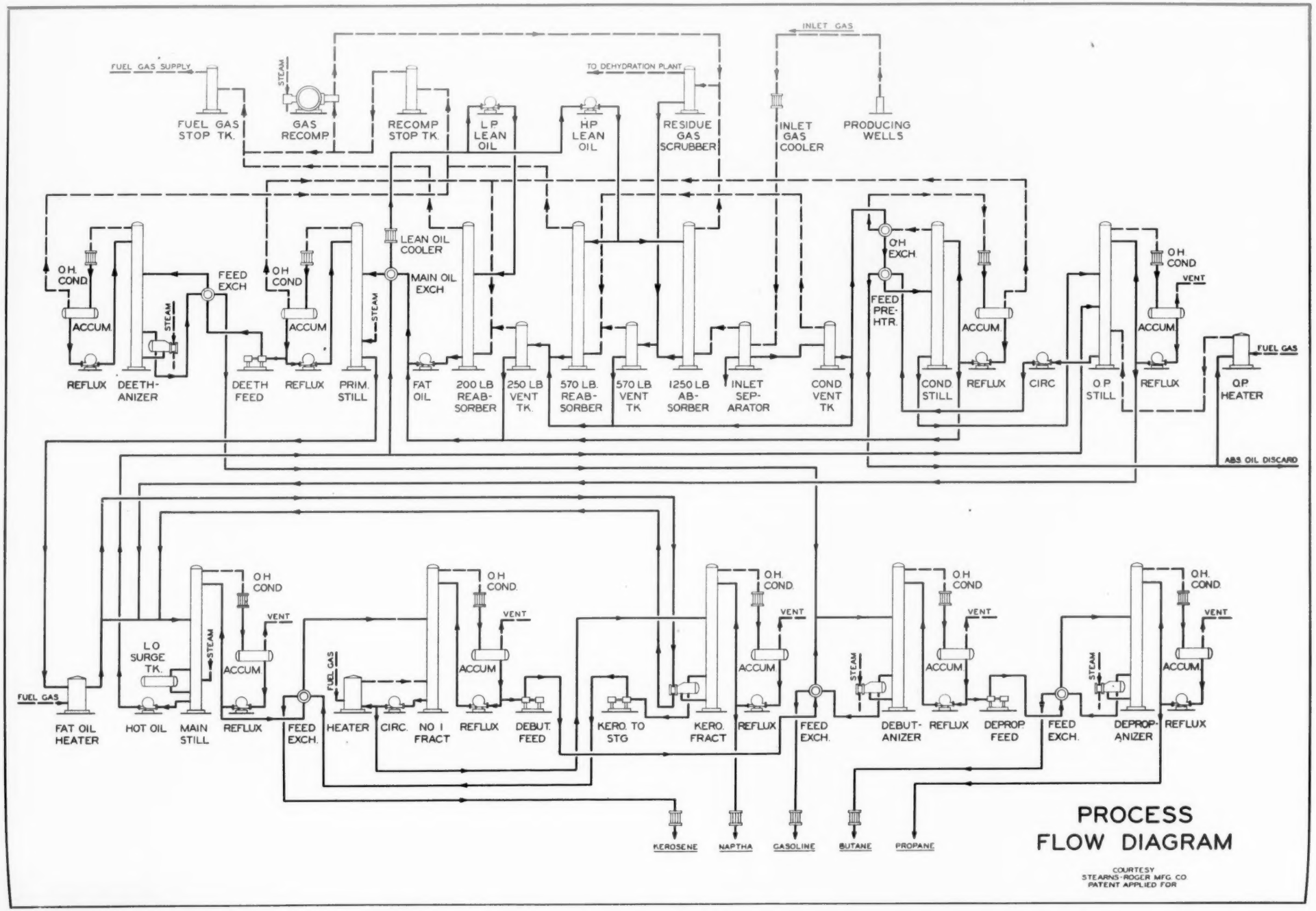

PROCESS FLOW DIAGRAM

COURTESY
STEARNS-ROGER MFG. CO.
PATENT APPLIED FOR

to shut down a Refinery

Source	Gravity API	Water %	Chlorides ptb. * as NaCl	Sulfates ptb. * as Na_2SO_4	Calcium & Magnesium ptb.* as NaCl
Texas, Duggan-Slaughter	31.8	0.05	191	8.3	151
Texas, Ector County	34.5	0.1	104	12.0	28.4
California, Dominguez	29.5	1.5	151	Trace	18.7
California, Santa Maria	15.5	0.7	110	1.0	19.3
Oklahoma, Wilcox Sand	41.3	0.2	81	4.2	19.2
Michigan, West Branch	32.3	0.1	141	10.8	45.5
Canada, Vermillion	15.2	1.0	305	Trace	84
U.S.S.R., Buguruslan	28.5	1.1	300	2.0	41
Egypt, Ras Gharib	18.4	2.4	1,085	4.0	165
Argentine, Cachueta	29.8	2.0	525	—	—

*ptb. = pounds per 1000 bbls.

It doesn't seem likely that such a small percentage of B. S. & M. in charging crude could cause trouble—but very small quantities of water often carry dangerous quantities of salts. Petreco research chemists have made extensive salt analyses of crude oils from all over the world. The table shows how low cutting crudes often carry high salt contents. (For more complete information, write for the *Petreco Manual on SALTS IN PETROLEUM.*)

In many refineries Petreco Electrical Desalting is the accepted standard process for salt removal. If your refinery is having trouble with plugging, corrosion, scaling or excessive down-time—have a talk with a Petreco Desalting Engineer.

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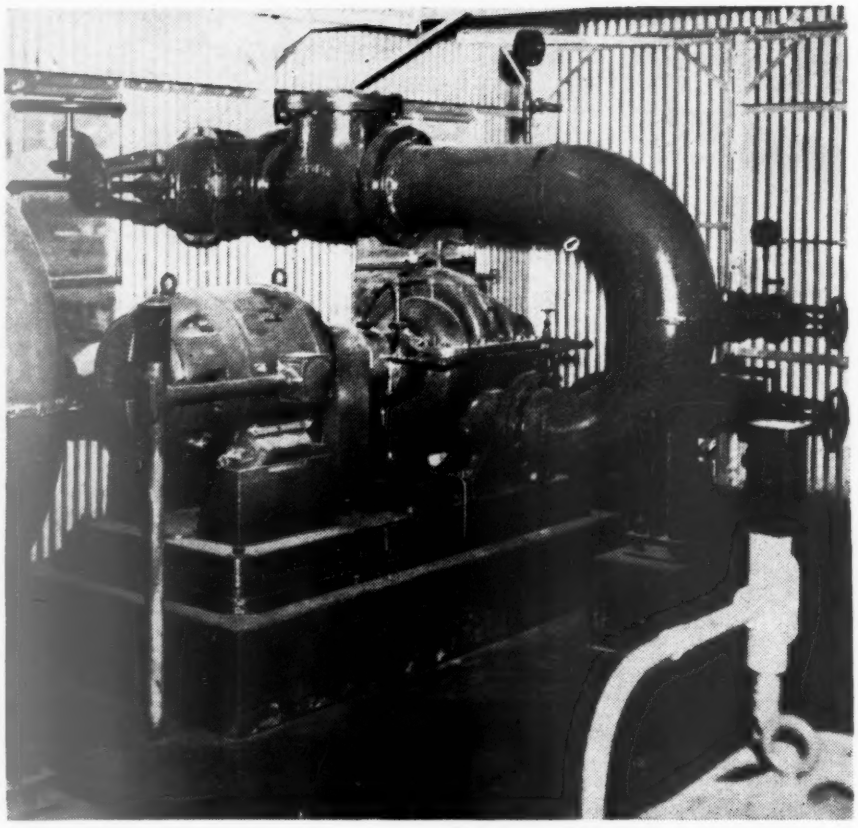
Representatives in principal producing and refining centers.

PETRECO

DESALTING ★ ELECTRICAL PROCESS ★ DEHYDRATING



Condenser water circulating pump driven by 30-hp. motor.

base of the oil-purifying still, and the base of the fractionator.

Electric power is generated with two 750-kw, 3600-rpm generator units, operated by multi-stage condensing turbines. One is used as a standby. The power is three-phase, 60 cycle, 480 volts.

Oil to the high-pressure absorbers is pumped by two six-stage, horizontal, split-case, centrifugal pumps, operated with an 875-hp. multi-stage condensing turbine. Each of these pumps will handle 700 gpm against a discharge pressure of 1300 psi.

One horizontal steam-driven gas compressor is used to handle the vapors from the deethanizer and the 575-lb. reabsorber. These vapors are pumped into the outlet of the high-pressure reabsorber. The 200-lb. reabsorber gas is used for fuel.

The plant is also equipped with a colorimeter that records continuously the Btu of the gas, and a gravitometer to record continuously the gravity of the gas. These two units are in the main office building, which also houses the laboratory.

The camp for operating personnel includes eleven 5-room houses and is laid out so that four more can be added.

The structure housing the offices and laboratory is of brick construction. The floors are rubber-tiled and the entire building is air-conditioned.

In case of emergency, the plant can be shut down from several emergency shutdown stations situated throughout the yard. These stations operate piston valves and regulators that shut off the inlet and outlet of gas, vent the absorbers and contactors to atmosphere, shut off the fuel to the boilers, shut down the high-pressure oil pumps, and turn snuffing steam into the direct-fired heaters.

● **Producing wells and gathering systems.** The Chicago Corporation and associates control approximately 23,000 productive acres, the plant being centrally located on this acreage. The company has 31 producing wells, one well is drilling, and another location is ready to drill. All but one are dual completions, averaging 6300 ft. in depth. The wells are completed in the Upper and Lower Pettit Zones, except for one well, which is completed in the Lower Pettit only. Wellhead pressure is approximately 2550 psi for the Upper Pettit and 2650 psi for the Lower Pettit.

In addition to its own wells, there are 17 wells of other operators connected to the plant. These operators have their own gathering systems and deliver gas directly to the plant.

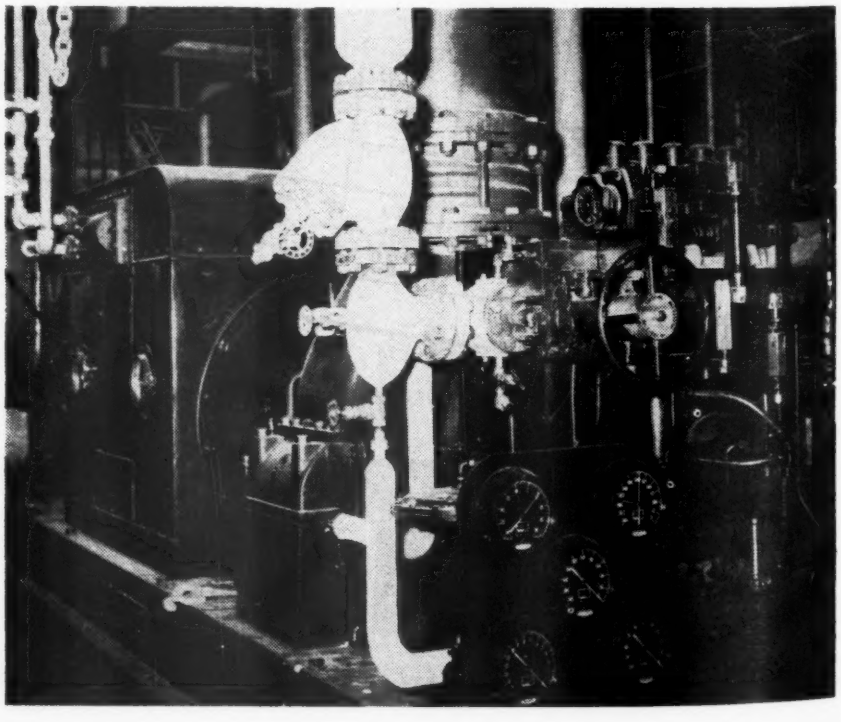
The Chicago Corporation has five 6½-in. trunk line gathering systems in the field, with 4½-in. lines connecting the wells to the trunk system. Outside operators have two gathering systems tied into the plant and another is under construction. Some of these lines are of larger diameter pipe than those employed by Chicago Corporation.

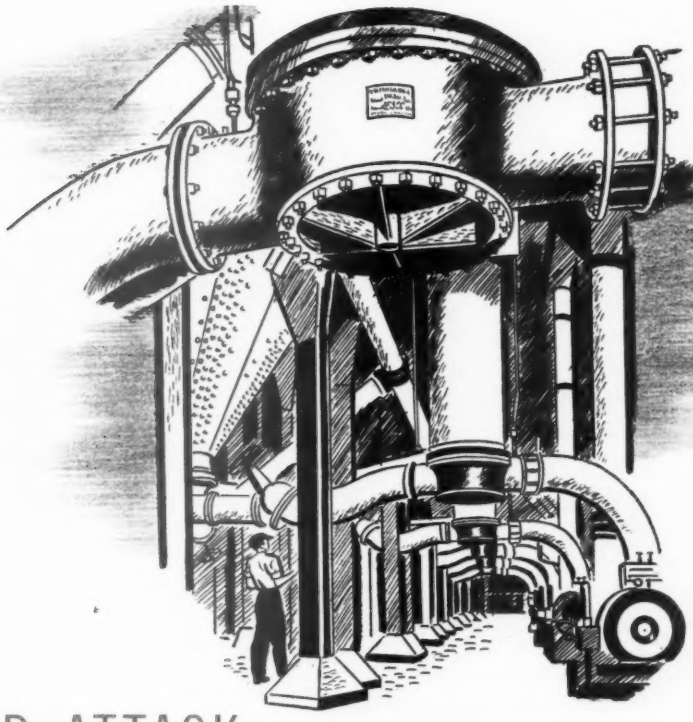
A feature of The Chicago Corporation's gathering system is that it is designed to withstand well pressures so that, in case of emergency, it can be blocked off at the plant without shutting in the wells.

The gas is metered at the well and an unusual hookup is employed that prevents freezing of the meters. Briefly, the gas-condensate is metered at wellhead pressure, the meter runs being placed between the christmas tree and the reducing chokes. At such high pressure the gas is "hot," which prevents freezing. After being metered, adjustable chokes reduce the gas to line pressure, at present 1400-1500 psi. In operation, this arrangement has resulted in less than 1 per cent differential between field meters and plant discharge meters. It has been unnecessary with this hookup to install heaters.

Already one operating problem has arisen that is being given considerable thought. Due to the fact that wells are prorated at such a low volume, surging of liquids in the gathering system has

Electric power is generated with two 750-kw. generator units operated by multi-stage condensing turbines.





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This equipment is used in a process which involves the continual circulation of a corrosive sulphite liquor. Paper mill men say the process would not be possible without the use of stainless steel for pipes, valves, and fittings. These installations have thoroughly demonstrated the effective resistance of the metal to the corrosion encountered in the industry. Stainless steel is also extensively used in the chemical and petroleum industries, where again corrosion is the enemy of low maintenance costs and uninterrupted production.

If you are interested in other new uses of stainless and other alloy steels, ask to receive the monthly publication, ELECTROMET REVIEW. If you need information on the production, properties, or fabrication of these steels, write our Technical Service Department. While we do not make steel, we do produce the ferro-alloys which are used in its manufacture, and our engineers have accumulated a fund of information on the use of stainless steel in many industries.

ELECTRO METALLURGICAL COMPANY

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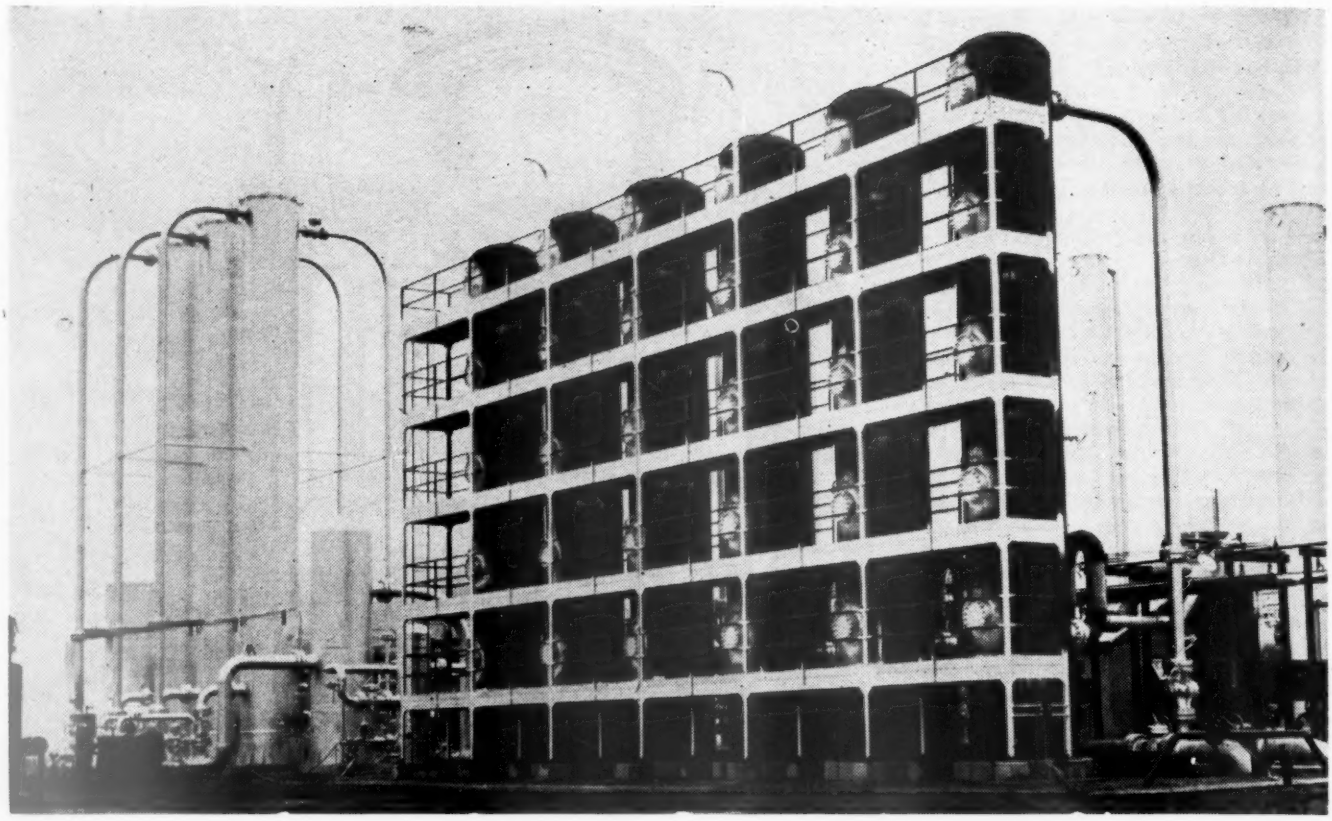
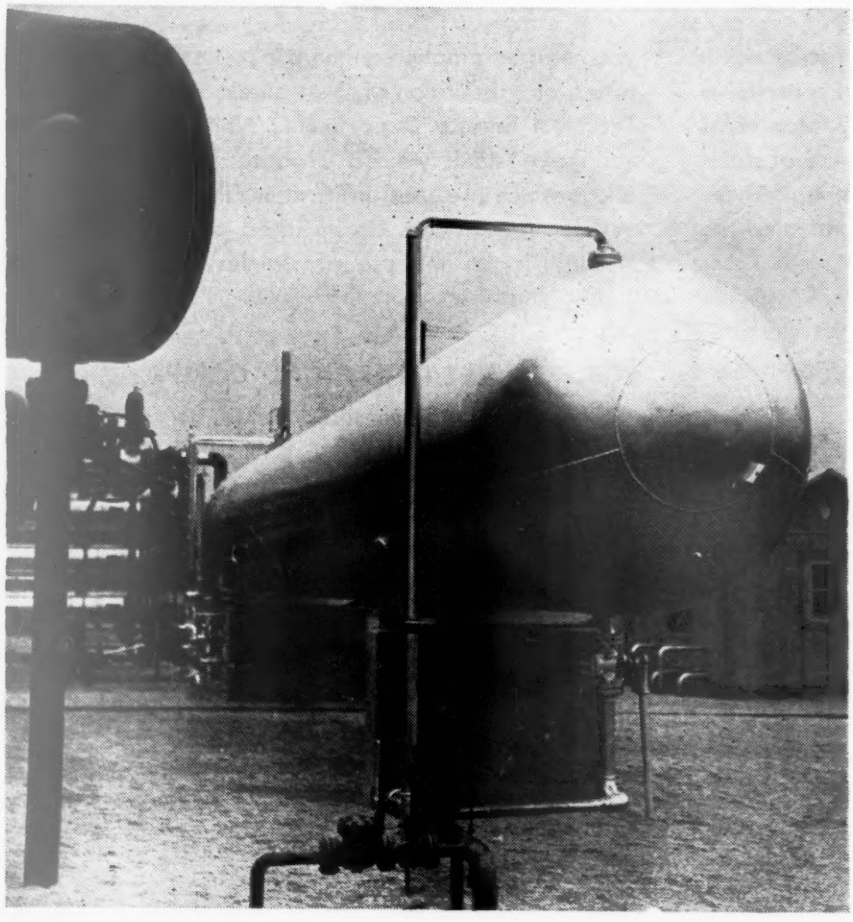
BEAUTIFUL ENDURING STRONG TOUGH



Before entering the pipe line, residue gas is dehydrated in the units shown at the right. At the left are the main absorbers.

Because the prorated wells produce at such small volume, surging of liquids has resulted. The surge tank shown here was installed to solve this problem temporarily.

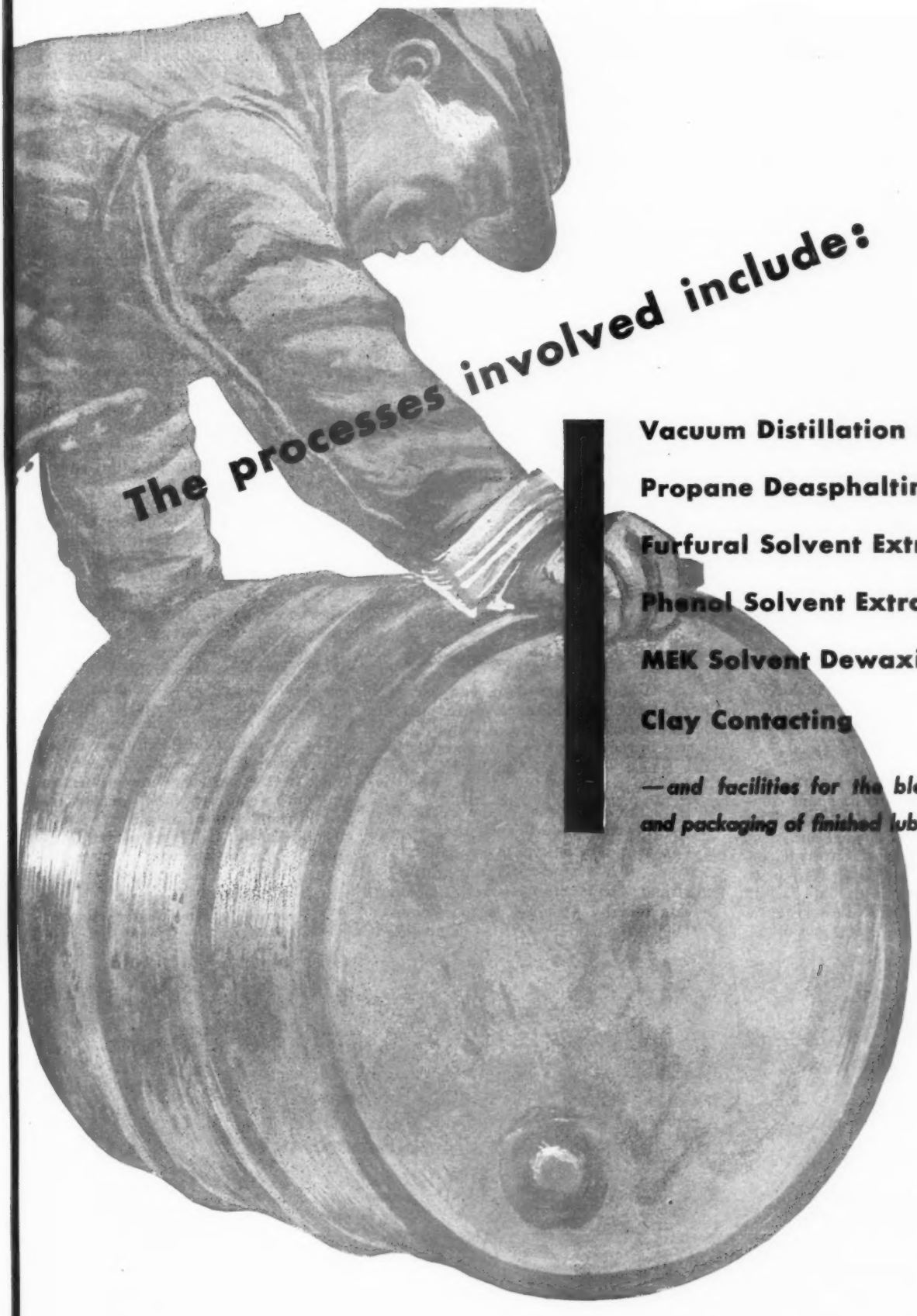


been experienced and this could develop into a major problem.

At the present time this surging is being handled satisfactorily with a surge tank at the plant, but as more lines are tied in and flowing conditions change this may not be adequate.

● **Historical background.** What is known as the Carthage gas field covers almost the whole of Panola County, Texas. There have been producing oil and gas wells in the Bethany area of Panola County for many years, but these wells are of comparatively shallow depth. The first of the deeper wells were drilled in 1936 in the eastern part of the county, along the Sabine River. At that time the demand for gas from this area was so negligible and the resulting price so low that little attention was paid to the field's possibilities. It took World War II, with the resulting scarcity of other fuels, to turn the gas industry's eyes to Panola County and to the possibilities of the vast potential reservoir of gas that subsequent drilling proved to exist in the Carthage field.

In 1941, N. V. Kinsey, an independent oil operator and drilling contractor of Shreveport, Louisiana, began the accumulation of a block of leases centering around the town of Carthage. It was two years before the block was completed and the first well spudded. This resulted in the discovery of the west extension of the field. This well is known as Feazel & Kinsey-H. C. Jordan No. 1, for in the meantime Kinsey had realized that the possibilities of the area were greater than his finances would permit him to explore and, therefore, interested another independent operator of Shreveport, W. C. Feazel. The latter purchased a substantial interest in the block of leases and



The processes involved include:

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agreed, as a part of the consideration, to stand the expense of drilling and completing the first well in the block. The well was drilled just beyond the west edge of the city limits of Carthage, on land owned by H. C. (Carl) Jordan. It was dually completed in the late fall of 1943, in the Upper and Lower Pettit zones, which are Oolitic limestones of the Lower Glenrose formation, and are of the Lower Cretaceous age. Approximately 90 per cent of the presently known reserves in the Carthage field are in these two zones. The rest is in the Hill and Travis Peak zones.

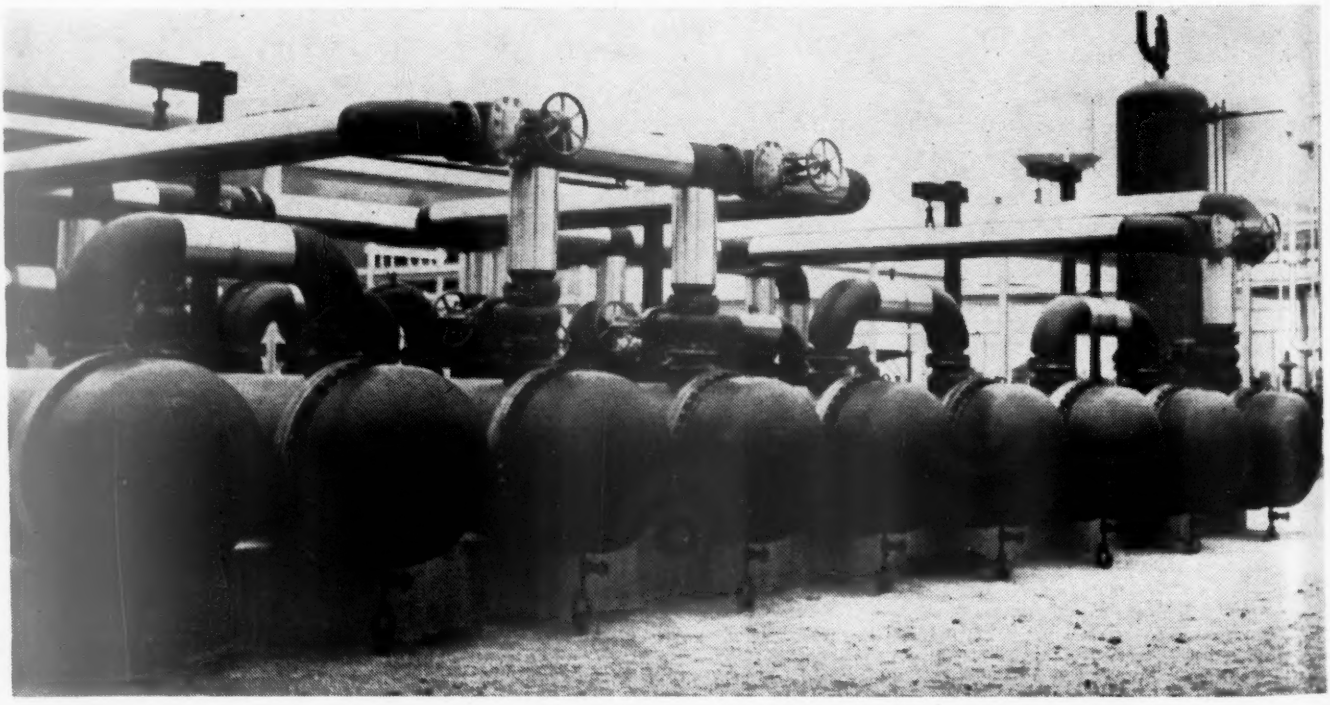
With the completion of the Feazel & Kinsey-Jordan No. 1 well, these operators found themselves in possession of a block of leases comprising several thousand acres with one well thereon having a daily potential of more than 200,000,000 cu. ft. of gas, but with no outlet for it that they considered commensurate with the value of this product as a fuel. At about this time these operators learned that The Chicago Corporation, through its then owned subsidiary company, The Tennessee Gas and Transmission Company, had begun the construction of a large natural gas pipe line from South Texas into West Virginia. This line was to come within 75 or 80 miles of Panola County, cross into and traverse the State of Louisiana, and then on to its terminus in West Virginia.

Feazel and Kinsey, in order to determine definitely whether they had sufficient gas reserves on their properties to attract The Chicago Corporation to Panola County as a partial source of its requirements to fill the Tennessee pipe line, went about two miles west of their discovery well and drilled a second well. This was the Feazel & Kinsey-E. N. Ross well, and it too was completed in the Upper and Lower Pettit zones as a dual producer with a daily potential equally as large as the Jordan well.

They then approached The Chicago Corporation and the Tennessee Gas and Transmission Company with an offer to supply a portion of the pipe line's requirements from the Carthage field. After several months' negotiation, Feazel, who owned 87½ per cent of the Feazel and Kinsey property in Panola County, sold to The Chicago Corporation, Clyde H. Alexander, S. N. Van Wert, and R. M. Briggs, 75 per cent interest in the two completed wells and the block of leases.

The new owners of the property, along with Feazel and Kinsey, who each retained a 12½ per cent interest, then entered into a contract with Tennessee Gas and Transmission Company to supply 100,000,000 cu. ft. of gas a day to the pipe line. As the line was taking gas in-

A group of nine heat exchangers situated in the processing area.



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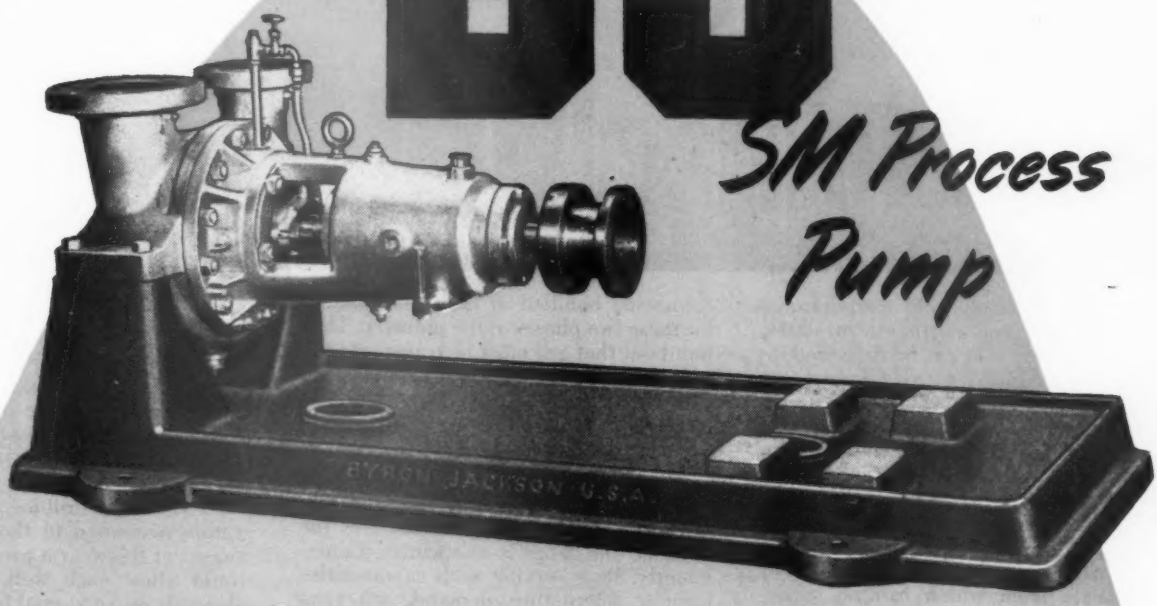

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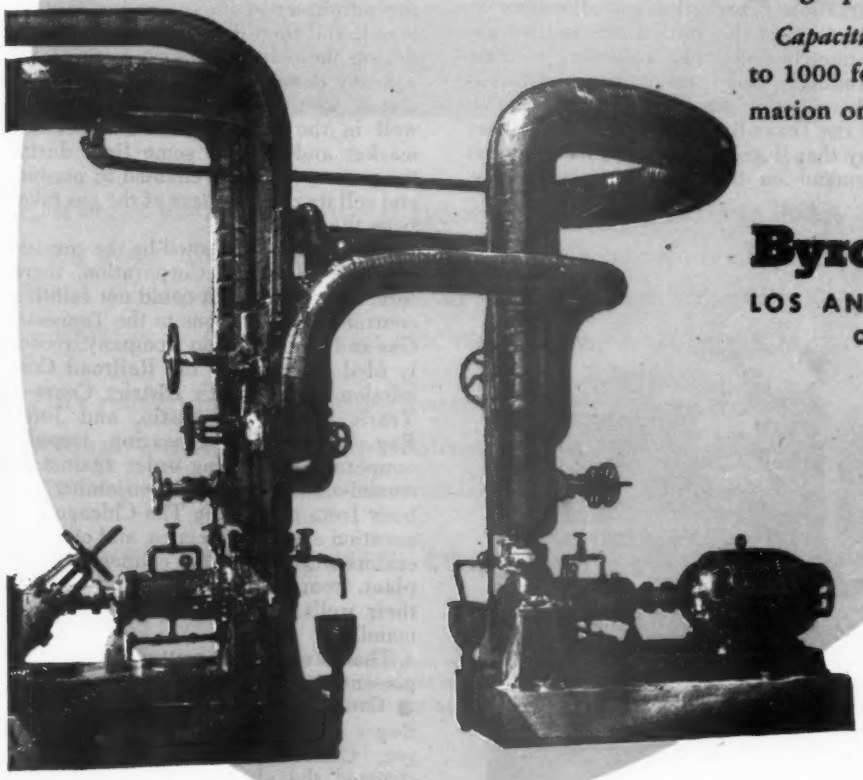

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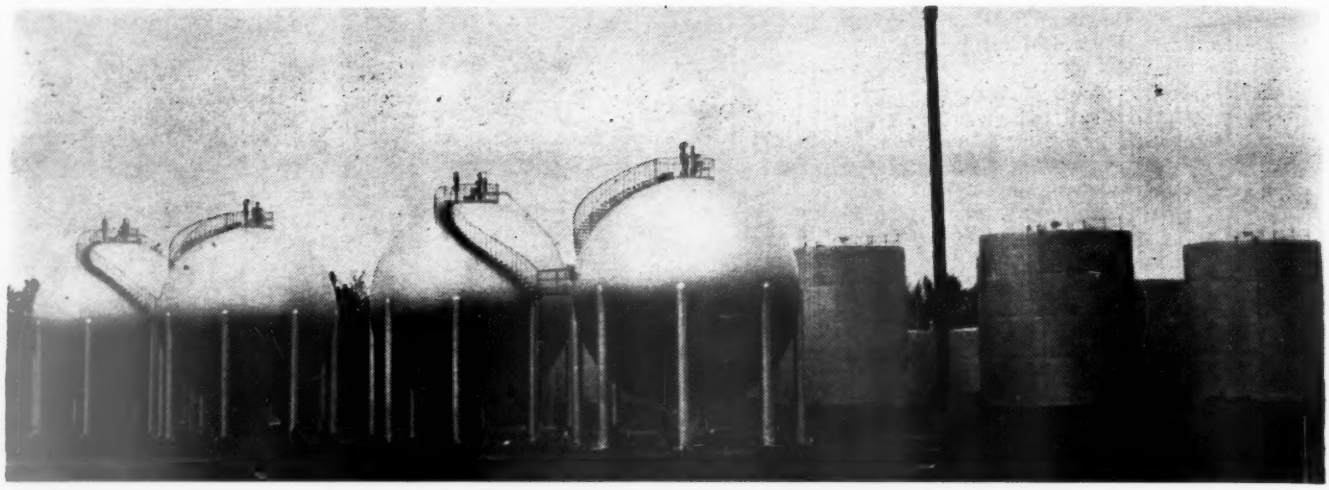
Two SM Process Pumps, installed by Refinery Engineering Co. Two-stage Turbine-driven pump (left) operates against a 775 foot head, motor driven pump (right) against a 530 foot head. Pumping 28° API reduced crude at 550° F.



A part of the products storage tank farm.

to the comparatively cold temperatures of the eastern and northeastern states, it was necessary that gas be delivered into the line almost totally free from liquids that would freeze when it reached the colder climate. As a result, The Chicago Corporation and associates began immediate construction of facilities to eliminate such liquid hydrocarbons, as well as moisture, from the gas. Also, Carthage gas is what is known as wet gas, containing considerable quantities of condensate from which can be manufactured gasoline, kerosine, butane, propane, and similar commodities. The Chicago Corporation and its associates therefore decided that they should also include facilities for the processing of condensate. This resulted in the modern gasoline absorption plant previously described.

● **Proration.** Carthage field gas producers and the Texas Railroad Commission have been at considerable disagreement regarding how the problem of proration should be handled. The producers contend that their problems are somewhat different from those of the oil producers and that the matter of proration cannot be handled in the same manner for these two phases of the industry. They point out that gas must be transported in pipe lines at the time it is produced; it cannot be stored on top of the ground as can other fuels, such as oil and coal, and transported when needed.

One of the principal uses of natural gas is for household and other heating purposes. This demand is small in the summer and large in the winter. Consequently, lines serving such communities have a fluctuating demand, whereas those lines such as Tennessee Gas and Transmission Company, which serves an industrial market, have an almost uniform demand both summer and winter. Because of these facts, producers, transporters, and distributors, in arranging to supply their markets, have problems that, although similar in some respects, are essentially different from problems of the oil producer, especially when considered in the light of proration and conservation. A proration and allocation order to meet the market demand for gas cannot be inflexible, according to these producers and transporters, and this is where their opinion diverges from that of the Texas Railroad Commission. They say that if gas proration to meet market demand on the basis of ratable take, is to be successful, there must be sufficient flexibility in the orders of the commission to permit those with constant daily, monthly, and seasonal demand, to meet such demand.

To solve this problem, a group of operators presented to the commission in August of this year a proration plan that would allow each well to produce its allowable on an annual basis rather than on a daily or monthly basis, as applied to oil.

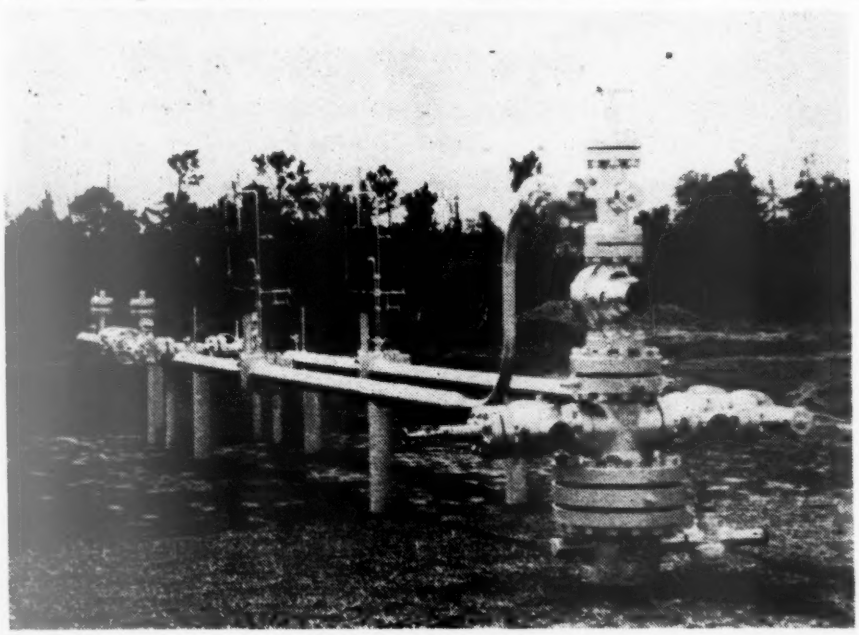
The mechanics of the plan, briefly, are that a well's daily allowable will be set up like a bank balance with a credit for under-production and a debit for over-production, with the provision that each well's account must be balanced at least once a year. By prorating on such a basis, a well could accumulate an allowable credit during the summer months when the purchaser of its gas had a light demand, and then draw against the credit during the cold months when there was a heavy demand. This plan, it was asserted, would further assure that every well in the field would be afforded a market and that at some time during the year it would be enabled to produce and sell its ratable share of the gas taken from the field.

This plan was rejected by the commission. The Chicago Corporation, therefore, asserting that it could not fulfill its contractual obligations to the Tennessee Gas and Transmission Company, recently filed suit against the Railroad Commission in the 128th District Court of Travis County at Austin, and Judge Roy Archer, after a hearing, issued a temporary restraining order against the commission, temporarily enjoining that body from preventing The Chicago Corporation and its associates, and other operators whose wells are connected to the plant, from producing sufficient gas from their wells to supply their market demand.

That is where the matter stands at the present time.

● **Construction contractor.** The Stearns-Roger Manufacturing Company of Denver, Colorado, engineered and constructed the absorption gasoline plant described in this article. ★★★

Placing of meter runs between christmas tree and reducing chokes prevents freezing of meters.



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FM radio communication aids operation of rigs

By **K. MARSHALL FAGIN,** *Field Editor*

EXCLUSIVE

ALTHOUGH two-way radio communication systems have been used in conducting drilling operations many times in the past, the development of small portable FM (frequency modulation) transmitters and receivers during the recent war puts the use of radiotelephone communication systems within practical reach of oil operators and drilling contractors who wish to test the money and time-saving convenience of this relatively new tool in conducting their operations.

The F. B. Paine Drilling Company of Dallas, Texas, is the first drilling contracting company that has installed a complete two-way FM radio telephone communication system. It is licensed by the Federal Communications Commission to operate a network of nine FM transmitters in the North Texas area on a frequency of 37.14 megacycles.

Each of its four drilling rigs is equipped with a radiotelephone transmitting and receiving set, and the other five sets are installed in toolpushers' cars, engineers' cars, or trucks. The rigs are situated in Jack and Young counties, Texas, at present. A car and a truck stationed at Wichita Falls are equipped with two-way sets, and cars at Graham, Jacksboro, and Dallas are similarly equipped.

● **Low power, short wave sets are alike.** All the sets are identical and are operated by regular 6-volt automobile storage batteries that are kept charged by the usual automobile generators. The generators for the sets at the drilling rigs are operated by V-belts from the drilling engine fan pulleys.

All rig receiving sets are kept on continuously, and the car receivers are kept on when the cars are being operated or the drivers wish to listen. The receiving sets and transmitters use about 8 amp. standby service, which is less current than the average car radio uses, and the transmitting sets use about 26 amp. when transmitting. It has been found advantageous, however, to set the car generators up, so that the batteries will remain fully charged.

In addition to the nine two-way sets, the toolpushers at Graham and Jacksboro are equipped with receiving sets in their homes that are kept on continuously when they are there. These are operated from the regular home lighting circuit, and enable men at the rigs to call or waken them at any time that it is necessary. Unlike the usual AM (amplitude modulation) radios, the FM receivers do not hum or crackle with static when they are turned on. Instead, they are silent until someone begins to transmit a message on the 37.14 megacycle frequency assigned this network.

● **Normal range limited to 60 miles.** One of the peculiarities of radio waves in the high frequency 30 megacycle region is their similarity to light waves, i.e., they travel in relatively straight lines and, therefore, cannot be received at distances much beyond the normal line of sight, and are greatly affected by the height of the antennas and the terrain between the transmitter and receiver.

For this reason, the drilling rigs with their antennas on top of the derricks can communicate over distances of as much as 60 miles in an area such as North Texas, but the rig to car range is limited to about 50 miles, due to the lower elevation of the car antenna, and the car-to-car range is usually about 30 miles. These distances are probably two to three times the line of sight distances, and may be greater when either or both antennas are situated on hills than when they are in valleys.

C. J. Paine, operator of the radio-equipped car at Dallas, for example, has found that he can communicate with one of the rigs from a point on the Dallas-Wichita Falls highway near Rhome, which is 24 miles north of Fort Worth, but he loses communication as he proceeds on northwest, because of driving downward through a valley.

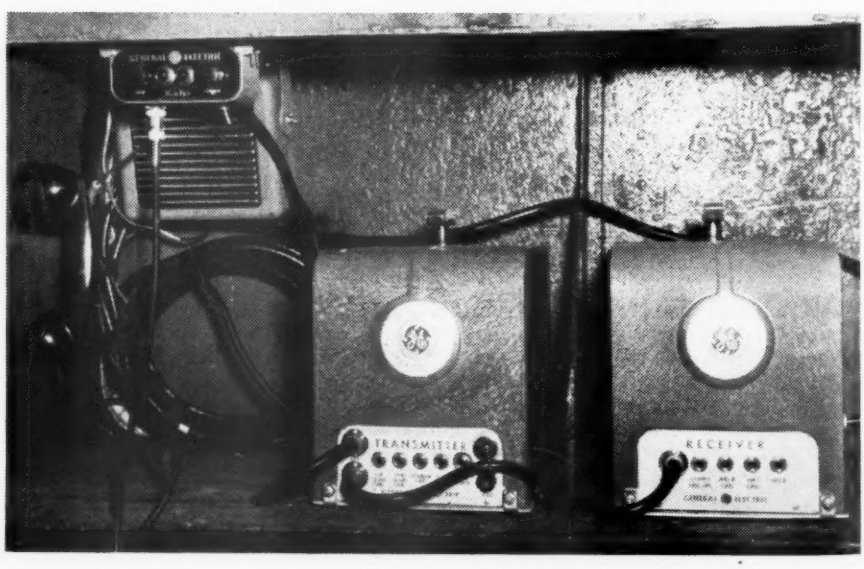
● **FM communication is clear.** One of the most important characteristics of FM radiotelephone communication is the clarity of reception in all kinds of weather, and the fact that two-way communication can always be established with any transmitter in the network that can be picked up on the receiver. In other words, voices that can be heard can be answered.

The receivers used by the Paine Drilling Company are designed with a "squelch" circuit that keeps the receiver silent until the incoming signal is strong enough to be audible when amplified. This together with the limited range of stations operating on this high frequency enables the Federal Communications Commission to allocate the same frequency to other networks throughout the country without interference between them. As a matter of fact, a large oil company operates a network of 30 or 40 units on the 37.14 megacycle frequency in the Florida, Louisiana, and Texas Gulf coast area.

The only exception to this freedom from interference is for brief periods of time associated with sun spot activity when the heavily ionized layers above the earth reflect signals from transmitters situated at distances of 1000 miles or more from the receiver. Such reception is called a "skip," and is a startling phenomenon to the uninitiated.

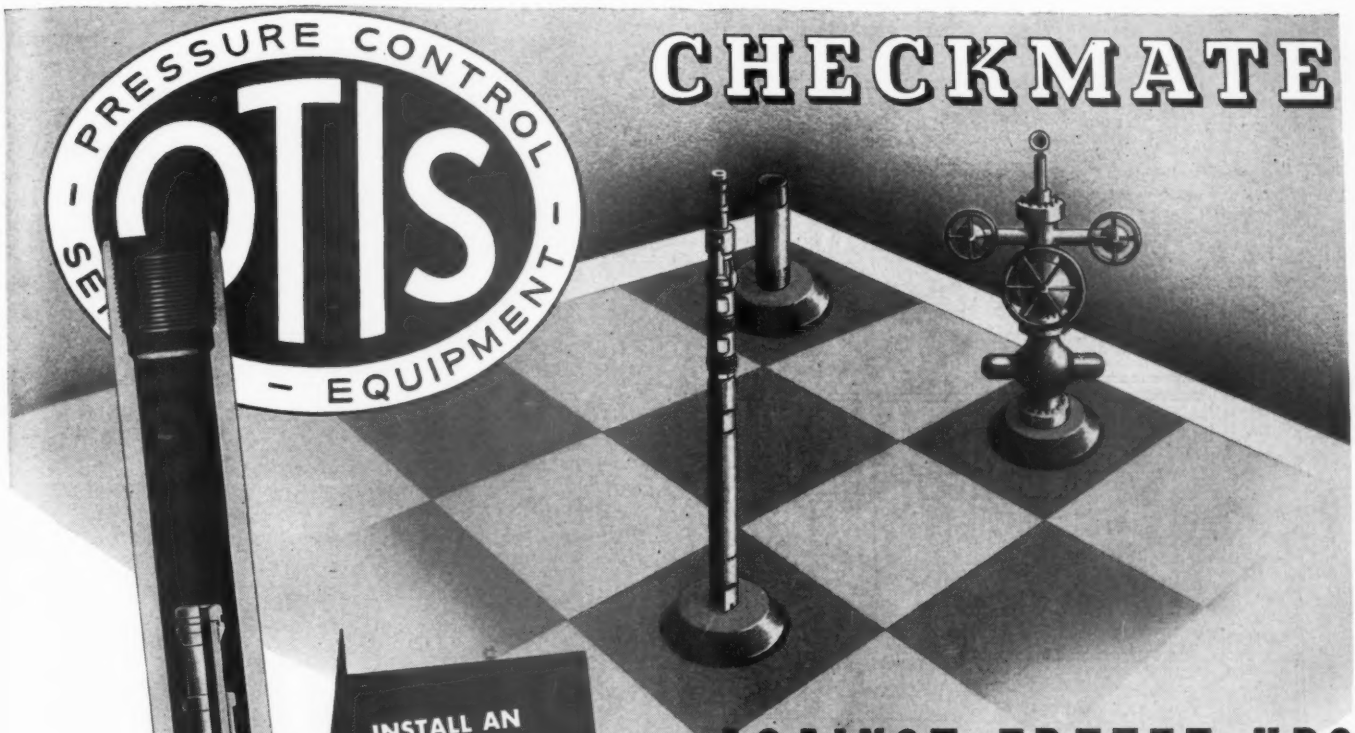
One of the drilling crews heard a voice on the loudspeaker order "Ed" to get a cementing truck to a well, and a worker on the crew by the name of "Ed" was quite puzzled until the voice identified himself as a member of a company drilling a well in Florida. The "skip" did not last long enough, however, for the Paine

The two-way FM radiotelephone set occupies only a portion of a shelf in the drilling rig tool house. The receiver (right) and the transmitter (center) weight about 30 lb. each. The control unit and telephone hand set are connected with the sets by plug type cables.



CHECKMATE

PRESSURE CONTROL — OTIS — SERVICE EQUIPMENT



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OTIS TYPE J LANDING NIPPLE

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Remember this standard combination for better winter production — an *Otis Type CJ Removable Bottom-Hole Regulator seated in an Otis Type J Landing Nipple!*

PRESSURE CONTROL — OTIS — SERVICE EQUIPMENT

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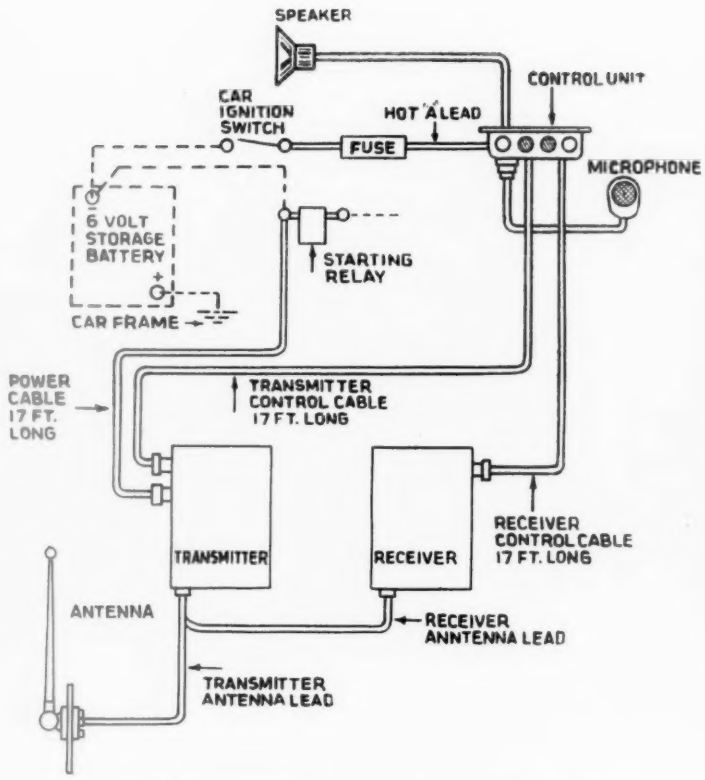
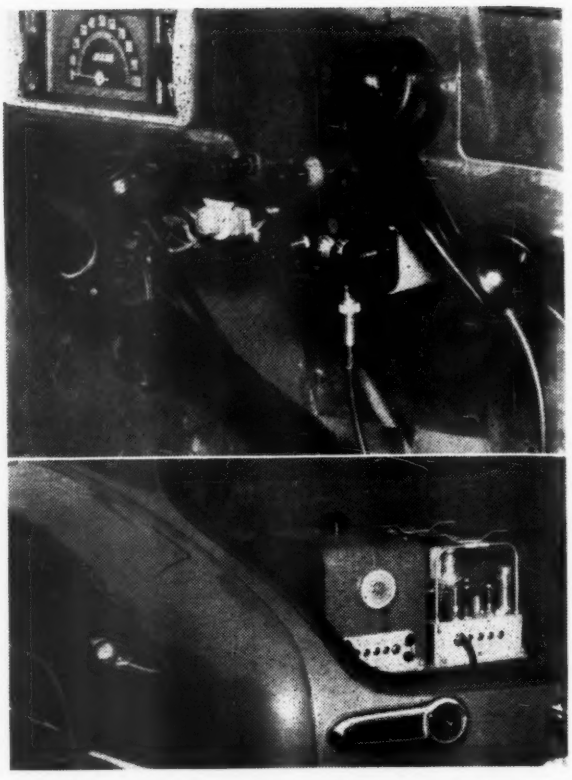


FIG. 1. The external connection diagram for the mobile two-way radiotelephone set shows how the equipment is connected to the automobile electric system.



Above is FM control equipment and hand phone set mounted on dashboard. Below, transmitter and receiver (with cover removed) are mounted in trunk compartment.

drilling crew in North Texas to reply (had they dared to break the rules against communicating with stations outside the network).

● **Rules governing operation of radios.** Contrary to popular belief, any company or individual that desires to utilize two-way radio communication of this kind in exploration, production, drilling, pipe line, or other phases of the petroleum industry will find that it is not necessary to be a licensed radio operator or to employ one regularly in order to obtain a temporary license on an annual basis for the operation of one or more mobile or portable sets.

It is only necessary to retain a person holding at least a second class radio operator's license, or to employ one to check and service the equipment at occasional times and to be responsible for its proper performance. This service can usually be obtained on a contract basis through the company or individual that installs the equipment.

The two-way sets can be operated by the regular employes of the company in the performance of their work. Calls may be made from station-to-station as telephone calls are made, but the identifying call letters or numbers assigned by the FCC must be given when signing off, or every 15 minutes during a continuous conversation.

Detailed logs of the conversation do not have to be kept by operators of fixed stations licensed under Part 17 of the FCC rules. The employes who use the sets simply sign their initials in the log book at the end of their tour. In case the equipment operates improperly, however, the details of the trouble should be noted. Results of transmitter frequency measurements that are made occasionally should also be kept in the log book, and all log book records should be kept at each station for a period of one year. Stations licensed under Part 11, however, must keep logs of all transmissions in accordance with existing rules.

Mobile radio units installed in vehicles must be effectively guarded against the possibility of the transmitter being operated during periods that the vehicle is not under the control of the licensed owner.

● **No restrictions on movement of units.** Although there are no restrictions on the movement of any of these mobile or portable two-way radiotelephone sets, the sets may not be moved out of the FCC area in which they are licensed without notifying the engineer-in-charge of the new area in advance, if practicable, or within 48 hr. thereafter. This is simply to minimize possible interference with other stations operating on the same frequency and to enable the FCC to keep up with the equipment.

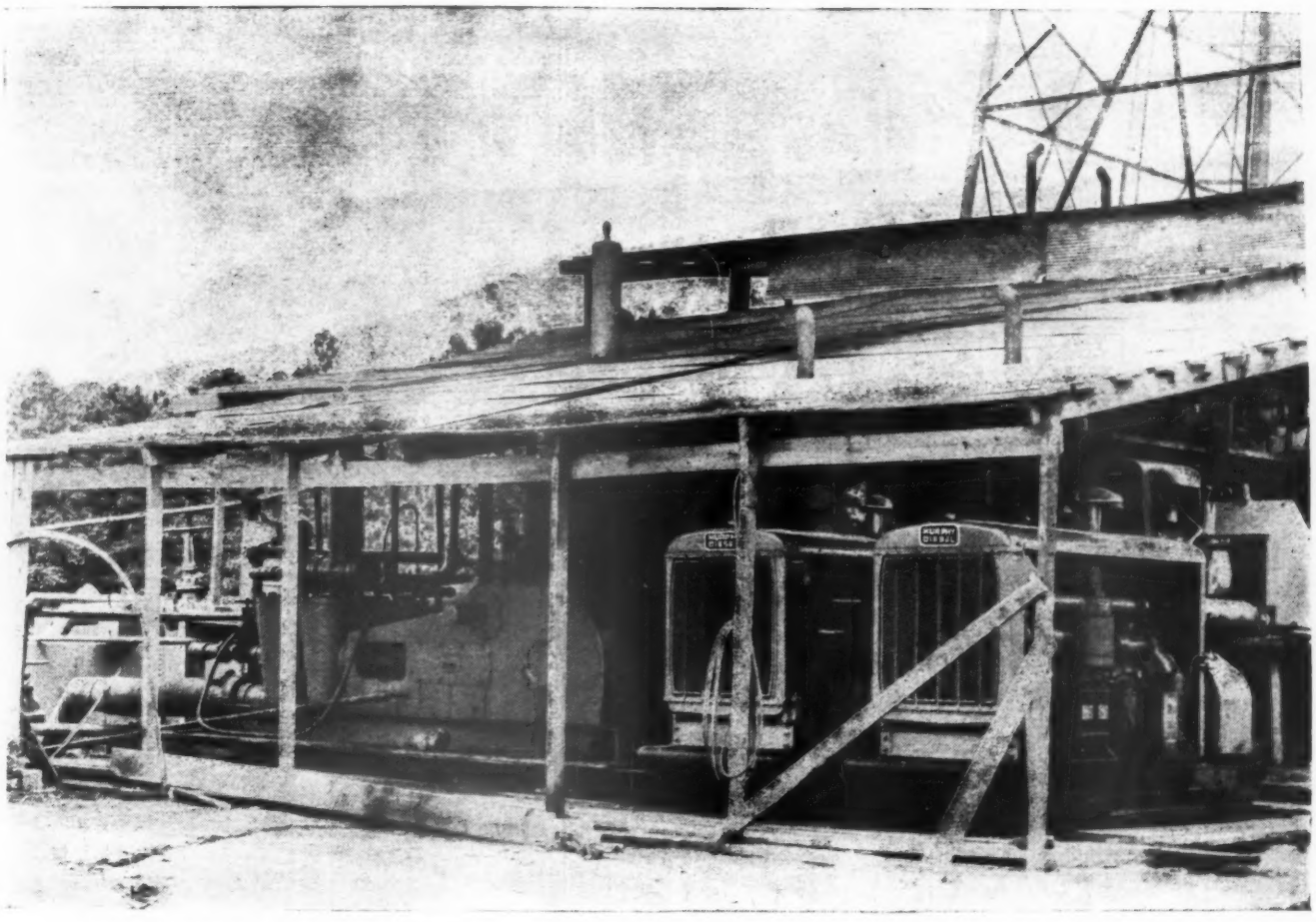
Applications for a permit to install and operate these two-way radiotelephone sets for utility or miscellaneous service in the petroleum industry may be made on FCC form No. 401-C. It is a relatively simple one-page form. Applicants should refer to Part 17 of the FCC's rules, which may be obtained from Washington, D. C.

Although the licenses to operate such mobile and portable stations are for one year, the FCC reserves the right to revoke or change the license without a hearing, in case it decides to reallocate the wave lengths. It is reasonable to assume that a company or individual investing in such equipment will find it possible to renew the license at the end of each year, or to change or dispose of the equipment without great loss should th FCC require it.

The Paine Drilling Company application was granted about four months after it was filed, but it is believed that future applications for this sort of radio service will require less than two months. The Paine license grants authority to communicate messages pertaining to the safety of life and property in accordance with Part 11 of the FCC rules governing miscellaneous radio services, and on a secondary basis, the license authorizes transmission of essential communications in connection with drilling and other operations in the industry.

The Paine Drilling Company network is situated in FCC District No. 10, which includes Oklahoma, New Mexico, and all of Texas except the Gulf Coast. The portable units at the rigs have been assigned the call letters KBKH, KBKN, KBKM, and KRQT. The mobile units in four cars share the call letters KBKQ, and the other mobile unit has been assigned the letters KHQT.

● **Availability and cost of equipment.** FM radiotelephone sets such as these used in the "Paine" network may be procured within the time required to obtain the installation permit. Thousands of such sets were manufactured and used dependably and effectively in combat during the recent war, and are now being used in police and many other services.



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Although ruggedly built for the heavy-duty service demanded in oil field operations, MURPHY DIESELS are compact in size and relatively light in weight . . . which helps to make them more readily adaptable to portable or stationary equipment or power plants.

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FIG. 2. Schematic diagram of the FM transmitter used in two-way radiotelephone system. All Paine Drilling Company transmitters are equipped with dynamotors.

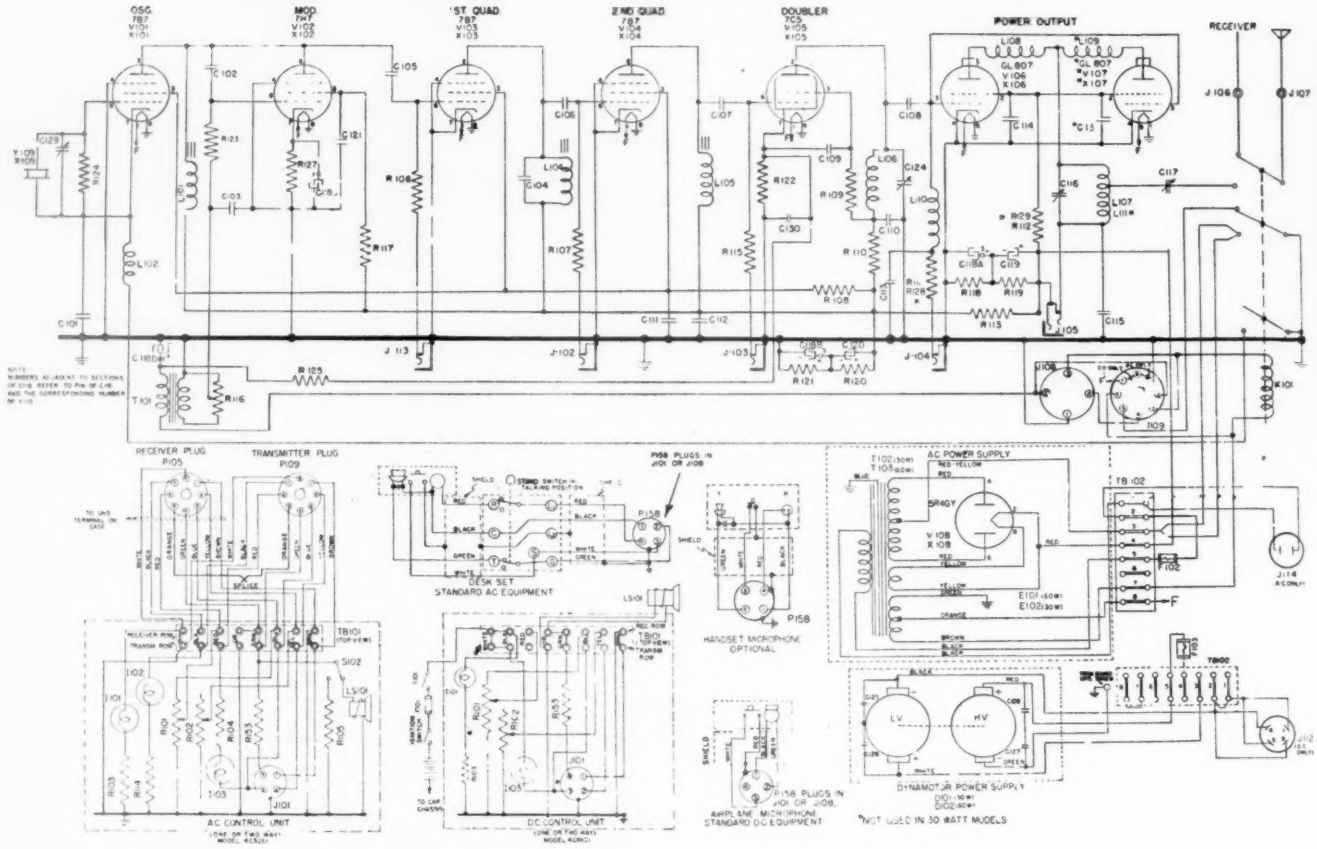
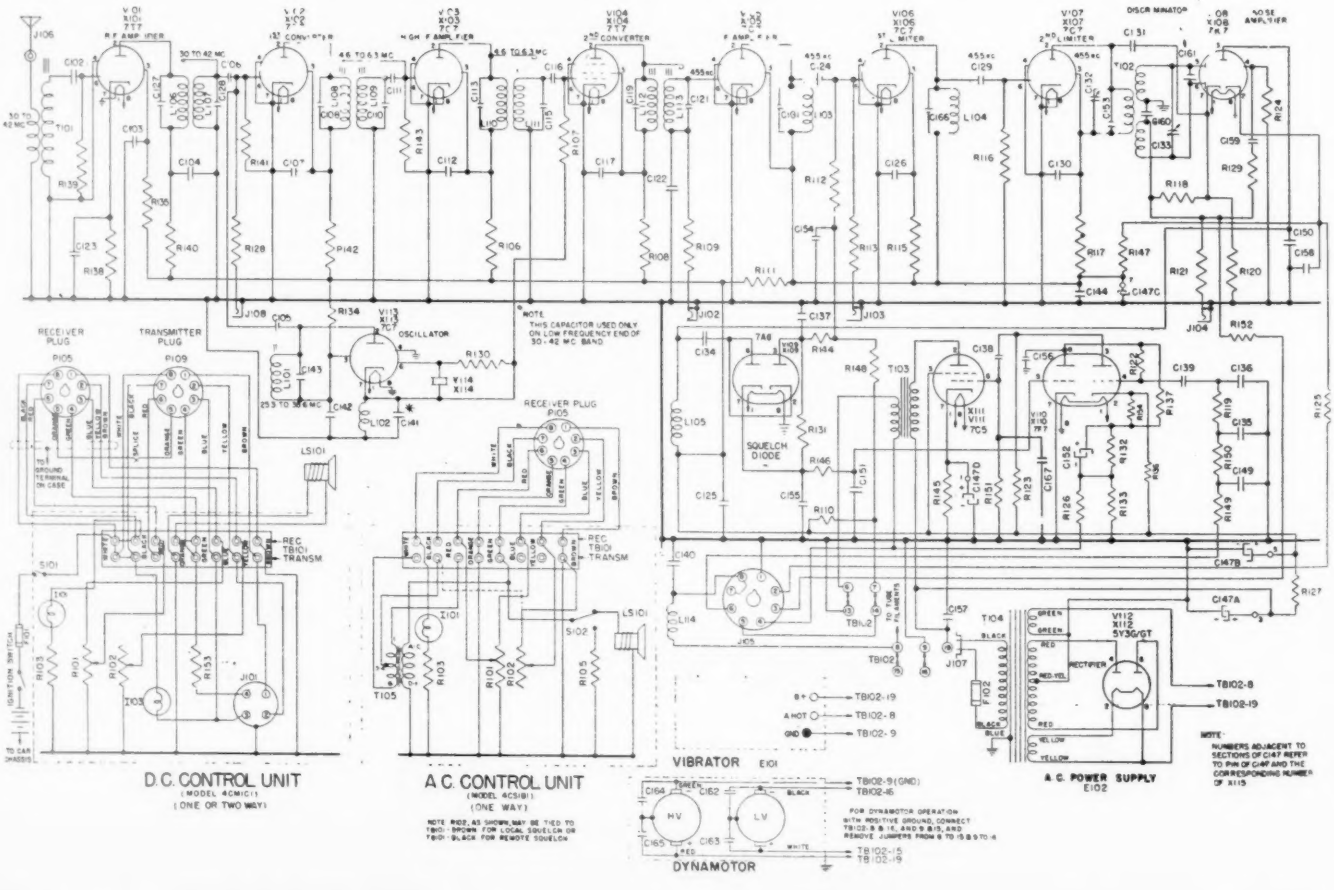


FIG. 3. Schematic diagram of the FM receiver used in the two-way system. Paine Drilling Company chose the vibrator for plate supply for all receivers.



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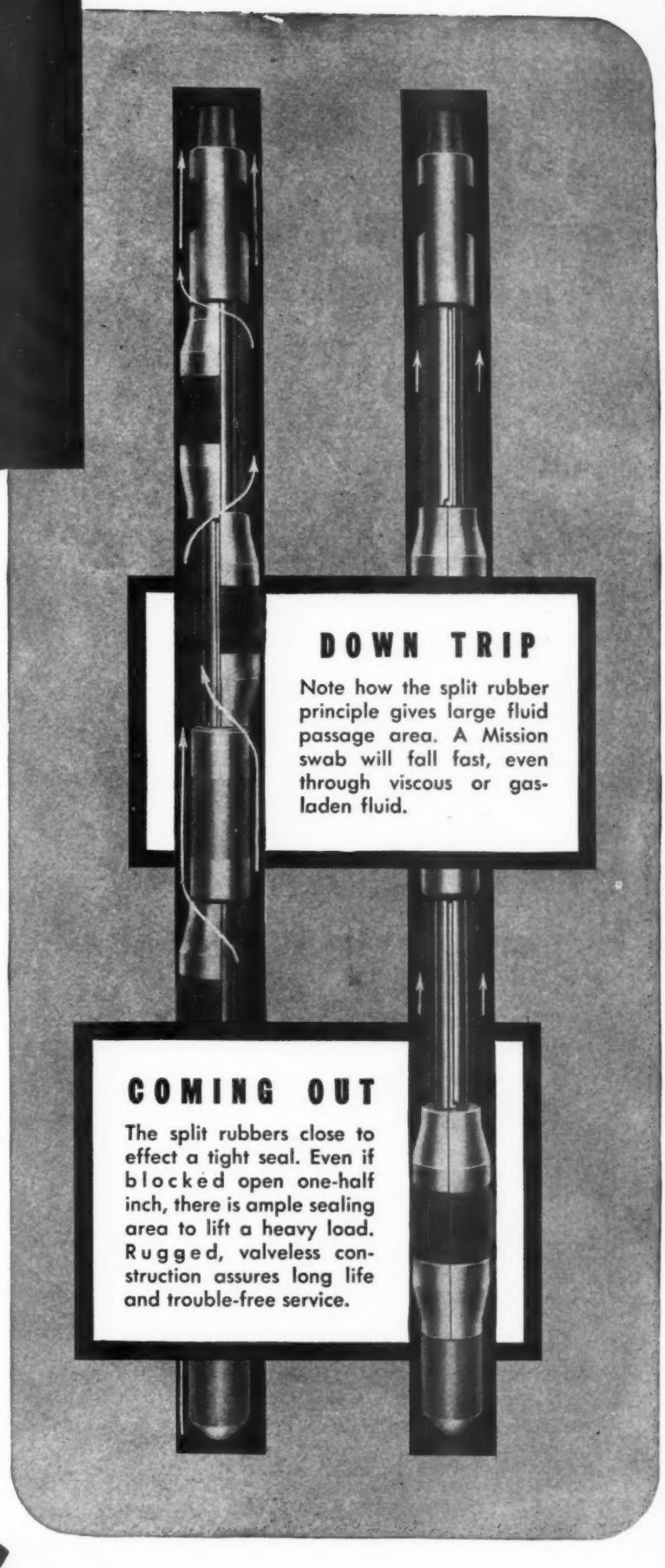
DOWN TRIP
Note how the split rubber principle gives large fluid passage area. A Mission swab will fall fast, even through viscous or gas-laden fluid.
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The split rubbers close to effect a tight seal. Even if blocked open one-half inch, there is ample sealing area to lift a heavy load. Rugged, valveless construction assures long life and trouble-free service.

Mission Valveless Swabs will save you time, money and materials on all your swabbing operations.

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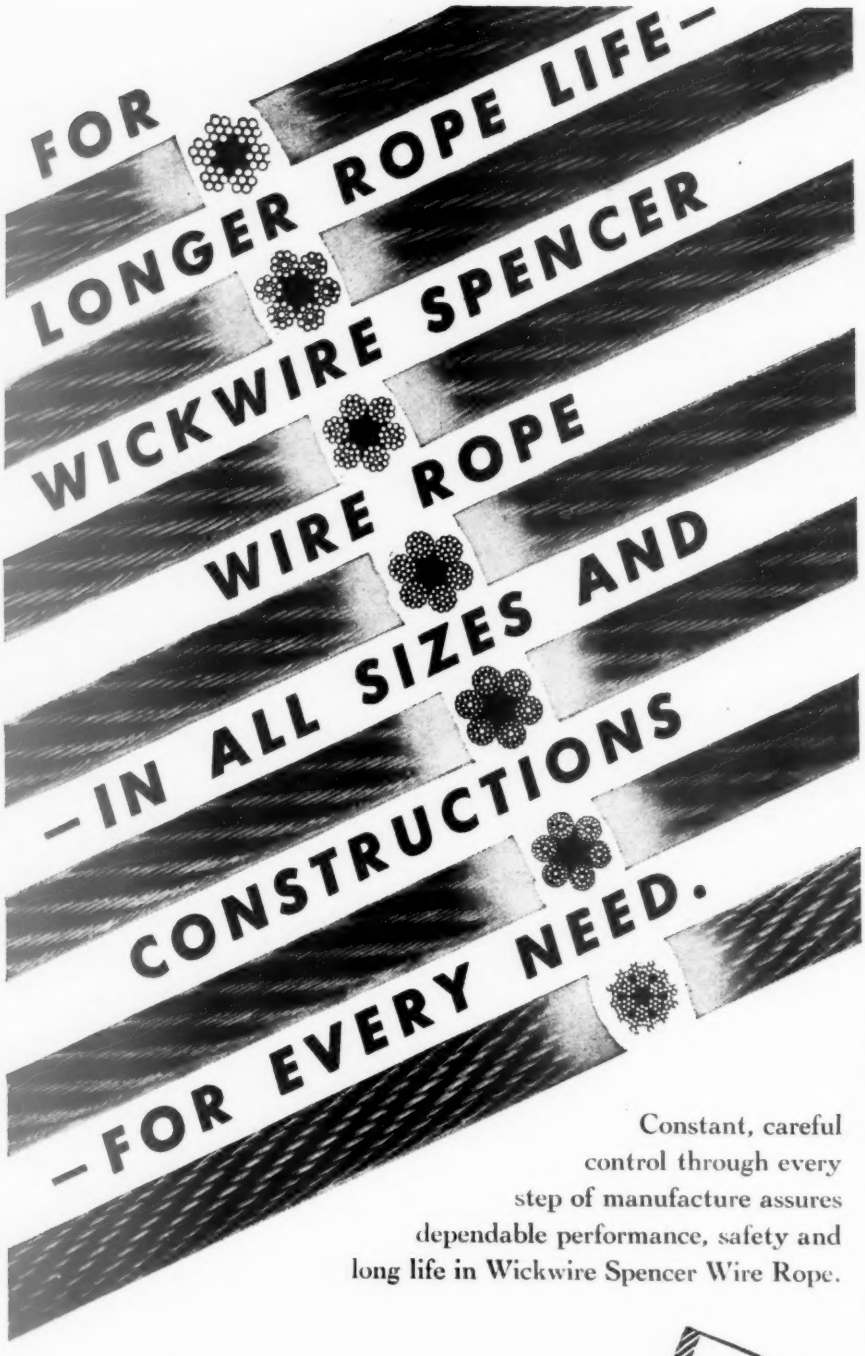

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They are designed to withstand hard service and rough usage.

With liberal allowance for all installation and initial adjustment fees necessary to put the sets in proper working order, the drilling rigs sets represent an investment of about $800, and the car sets represent a total investment of about $600. The "Paine" network of four drilling rig sets and five car sets represents an investment of $6200 on this basis.

● **Installation and operation.** The external connection diagram of the mobile two-way unit (Fig. 1) and the accompanying pictures reveal the relative simplicity and unitized nature of the installations. All the transmitters are powered with dynamotors and for plate supply the receivers are equipped with vibrators. The schematic diagrams of the internal circuits of the transmitters and receivers (Figs. 2 and 3) show the alternative sources of power and the required control circuits.

The equipment in a car can be removed and placed in another car in a few hours' time, in case a new car is purchased or the old one needs to be overhauled or laid up for a protracted period of time. The plug-type cable connections facilitate such switches.

A shelf in the toolhouse at the drilling rig has been found a satisfactory place for the installation of the set. A 240-amp., 6-volt storage battery that will maintain communication for a period of 30 hr. or more during rigging up and tearing down operations is used for standby service. The battery is charged by an automobile generator that is mounted on one of the drilling engines and driven by a V-belt from the fan pulley. A loudspeaker from the receiving set is extended by cable to the drawworks. It is loud enough to be heard clearly from any part of the rig above the din of drilling, but transmission is carried on only through the telephone-type microphone connected to the control unit in the toolhouse. The antenna for the drilling rig set is extended by cable from the toolhouse to top of gin pole on derrick.

Inasmuch as all the sets in the network are pre-tuned to the assigned frequency of 37.14 megacycles, the control units have only a "press-to-talk" button, a volume control knob, and a "squelch" control knob. The "squelch" control is the regulator for the circuit that cuts out background noise when no signals are being received.

● **Radio system saves time and money.** Although the Paine Drilling Company has had its present system installed only four months, C. J. Paine estimates that it has already saved enough miles of travel by the toolpushers, and enough shutdown time by the four rigs to repay more than the initial investment, and the upkeep is relatively neglible.

The value to the oil well drilling industry of a new tool such as this is as difficult to estimate generally as the value of the telephone or the telegraph, and it is likely to become as commonplace. It will certainly aid drillers to make more hole at a lower cost, especially in isolated areas. ★ ★ ★

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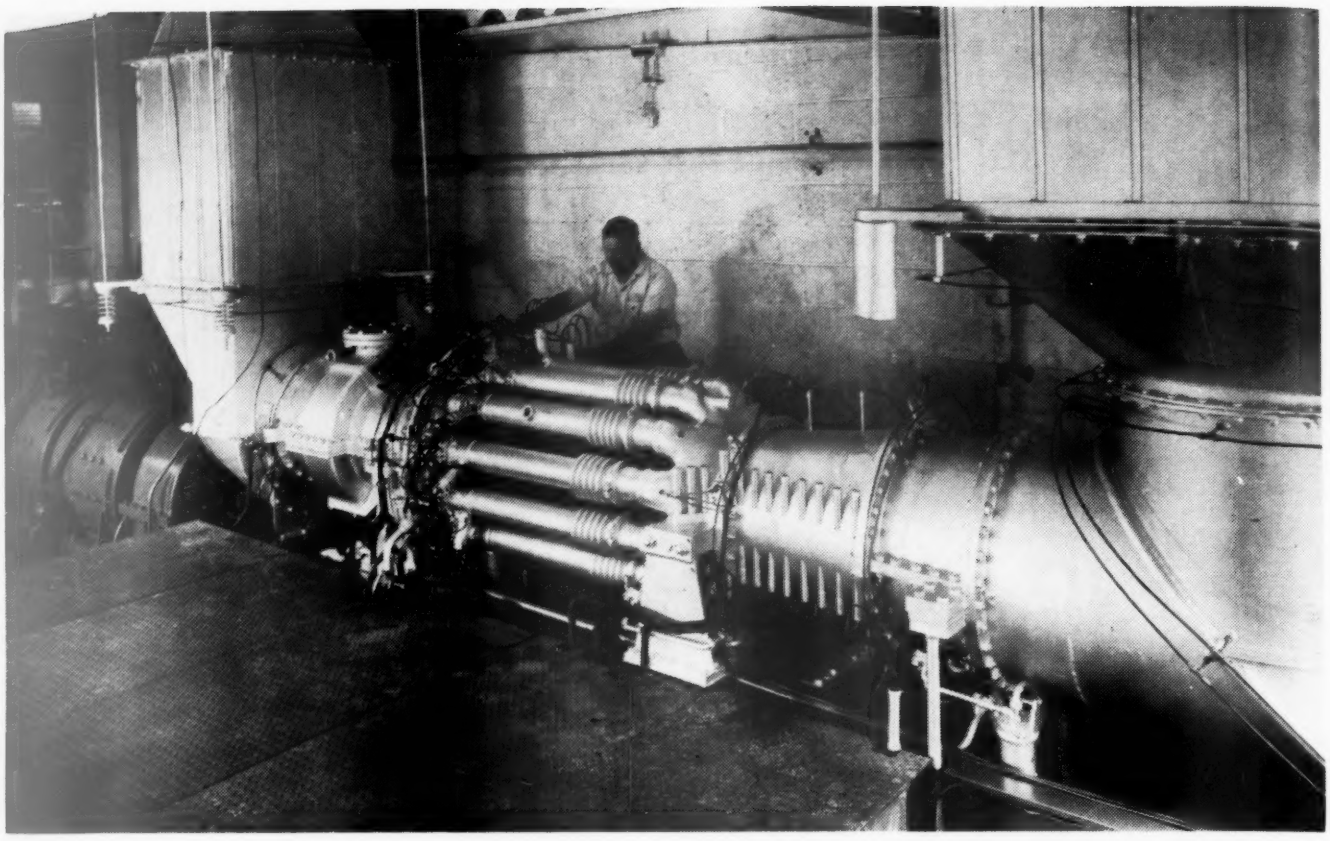

The generator set on test at South Philadelphia works.

A 2000-hp. gas turbine generator set*

By **THOMAS J. PUTZ,**† Westinghouse Electric Corporation

An experimental 2000-hp. gas-turbine generator set that weighs only 19 lb. per hp. and starts in 1½ minutes or less has been developed for industrial, central station, marine, and locomotive applications. Occupying but ¼ cu. ft. per hp., its light weight, compactness, and quick starting and loading response make possible among other things a gas-turbine-electric locomotive less than half the length and two-thirds the weight of its equivalent in a diesel-electric.

Burning No. 6 (bunker "C") fuel oil to compensate economically for an expected thermal efficiency of its simple open cycle of 20 per cent at full load, the gas turbine generator set operates at a top temperature of 1350°F.—the maximum practical temperature using currently available materials without resort to cooling. The simplest type of open cycle, consisting of only a compressor, combustor, and turbine is employed in order that operating experience on these major components may be most quickly acquired, and the useful output is absorbed by a double-armature d-c. traction-type generator connected to the turbine through a single reduction gear.

● **Applications.** The possible applications of such a simple open cycle gas turbine are numerous. As a locomotive prime mover it can be built in large powers within a single cab and would require no cooling water. Four of the present units could be installed in a standard cab.

For marine auxiliary applications it may find a place as a standby power unit and as power booster, and with regenerators and intercoolers added to raise thermal efficiency it may serve as the main drive. For large ships, however, the closed cycle may be adopted to reduce weight and space.

In the central station field the simple open cycle gas turbine lends itself particularly on the ends of transmission lines to use as a standby unit for peak service. The expense of banked boilers and spinning reserves required of central station steam plants could be reduced by the substitution of low cost, quick starting gas turbines strategically located to cover system peak loads.

Other applications such as portable power plants in the gas fields, power units for gas transmission lines, and power plants for factories where circumstances make it advantageous are all attractive possibilities.

● **Simple in operation.** In operation air is taken in by the compressor through the inlet metering nozzle and silencer and compressed to pressures of 30 to 75 psia, depending on the load carried. Fuel oil is mixed with the compressed air and burned in the combustors, the amount of fuel burned being controlled to limit the temperature of the gases to between 700°F. and 1350°F. at the combustion chamber outlets. The hot gases are expanded through the power-produc-

*Presented before the Annual Meeting of the American Society of Mechanical Engineers, New York, December 5, 1946.

†Thomas J. Putz is manager of the gas and locomotive turbine section, Steam Division, Westinghouse Electric Corporation.

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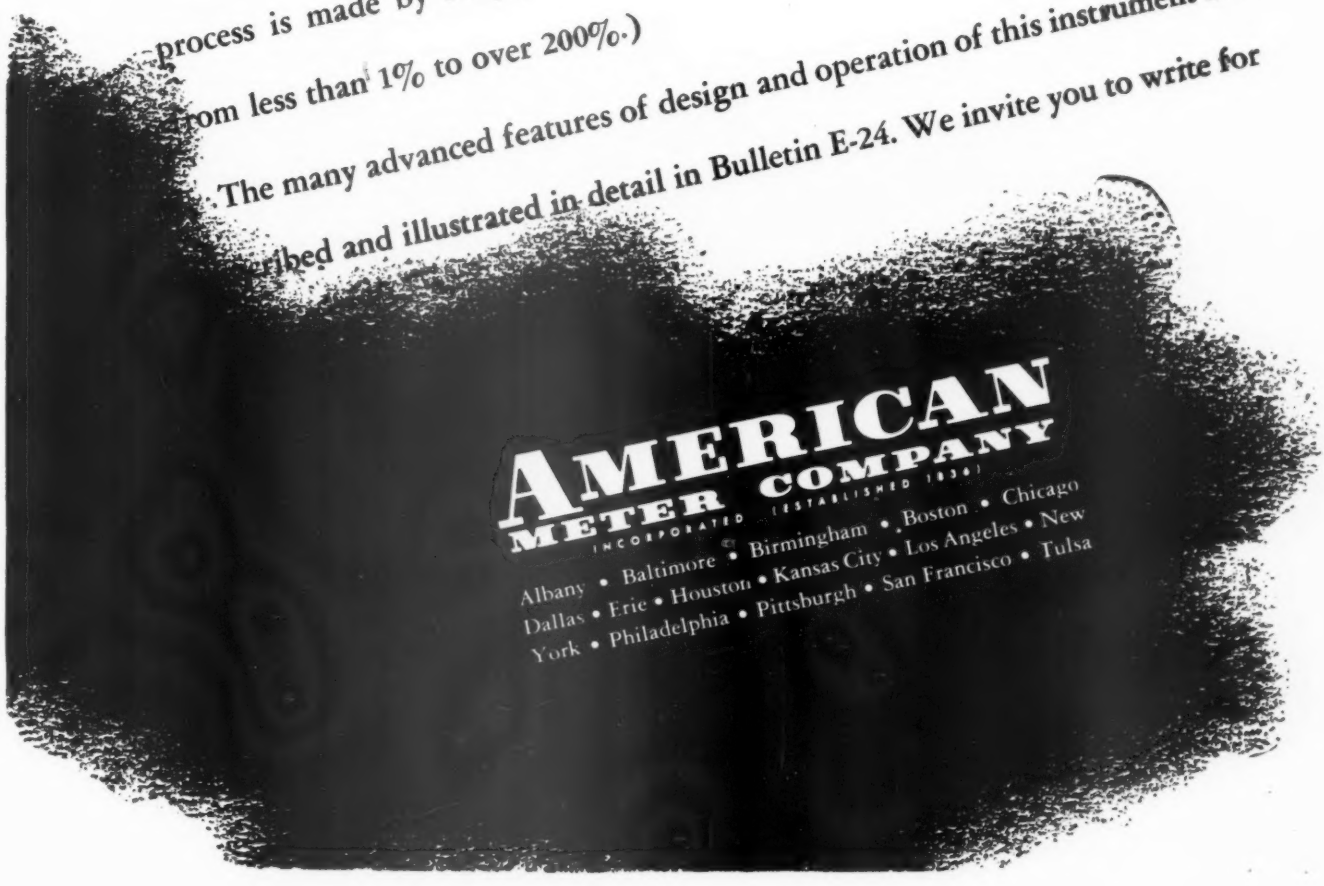
The many advanced features of design and operation of this instrument are described and illustrated in detail in Bulletin E-24. We invite you to write for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ing turbine and the resultant exhaust gases pass through a diffuser, elbow, and silencer to the atmosphere.

The turbine develops approximately 6000 hp., of which 4000 hp. is used to drive the compressor. The remaining 2000 hp. is the useful output delivered to the d-c. generator. The full load speed of the turbine and compressor is 9200 rpm whereas the generator speed is 1200 rpm.

● **General arrangement of components.** The complete assembly measures 26 ft. long, 3½ ft. wide, and 6 ft. high. Components are arranged in order from one end to the other of exhaust diffuser and elbow, gas turbine, combustors, compressor, single reduction gear, and d-c. generator. The straight line arrangement saves piping, space, and weight and keeps pressure drop to a minimum. The total weight of 38,000 lb. is divided approximately one-third to the turbine, compressor, combustors, and gear; one-third to the bedplate and accessories; and one-third to the d-c. generator.

● **Components in detail. Compressor.** The compressor is of the axial flow type, designed to pass 25,000 cfm of air at a pressure ratio of 5 to 1. It has a maximum speed of 9200 rpm and the pressure ratio is varied from 2:1 to 5:1, depending on the load carried, by changing the speed.

It contains 20 stages of non-symmetric blading designed so that the major pressure rise occurs in the rotating blades. The latter have a constant tip diameter of 18⅜ in. and vary in height from 3 in. at the inlet to 1½ in. at the discharge. The blades, unshrouded and profiled at the tip, are forged from 12 per cent chromium steel stock similar to that used in steam turbine work. The serrated root fastening is machined in the base by using a formed milling cutter. The blades are caulked into serrated grooves cut in the rotor.

Stationary blades are precision cast of 18-8 stainless steel and are caulked into grooves cut in the cylinder wall. They too are unshrouded and profiled at tip.

The rotor is made of a solid carbon steel forging and the cylinder of welded steel plate. All air seals on both ends of the compressor are of the labyrinth type. The compressor, being solidly connected to the turbine, has the greater part of its thrust balanced by the turbine thrust thus eliminating the need of a dummy. The small remaining thrust unbalance is taken by a standard segmental shoe type bearing, located on the discharge end of the compressor. The journal bearings are pressure lubricated sleeve type.

For test purposes, a bleed connection has been provided after the eighth stage, but it has proved unnecessary and will not be provided on future units.

● **Compressor diffuser.** The air flow passes from the compressor through a diffuser where the velocity is reduced and transition is made from an annular passage to twelve circular passages. The diffuser is made of castings welded together.

FIG. 1. Cross-section of 20-stage compressor used in the gas turbine.

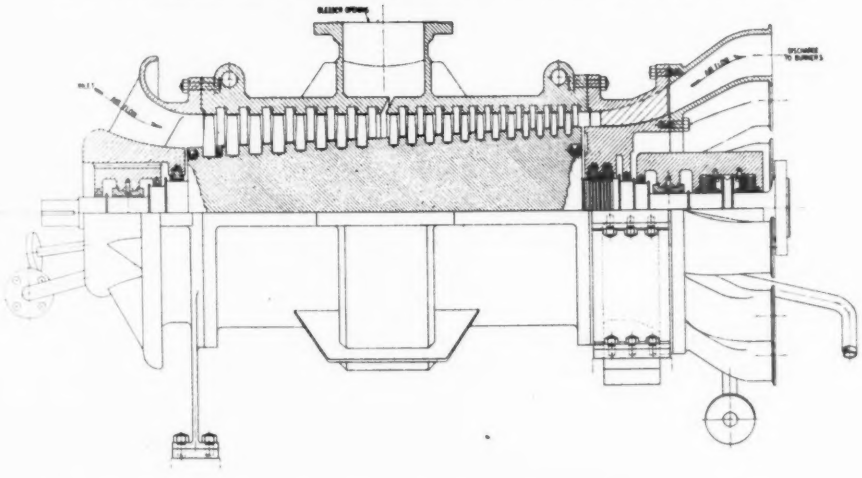
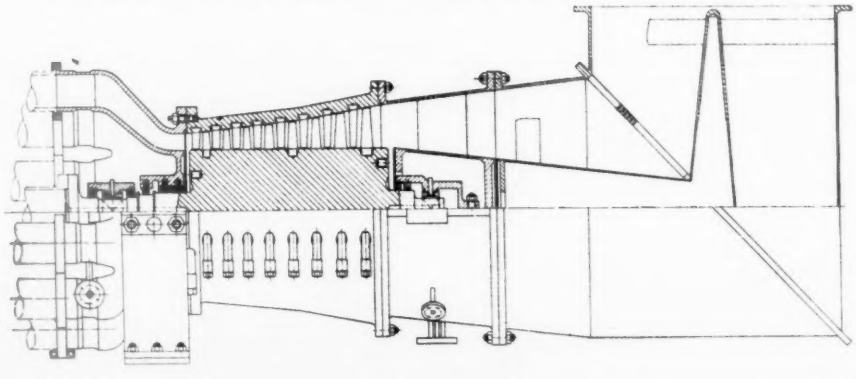
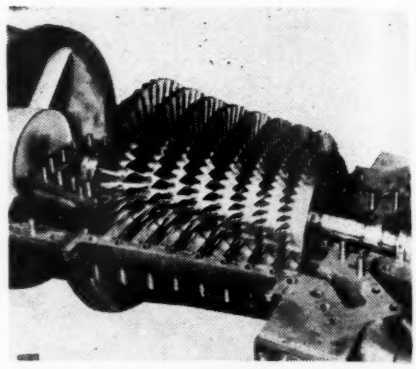


FIG. 2. Cross-section of turbine showing exhaust diffuser and elbow.





Turbine rotor showing cobalt-chromium-tungsten alloy blades.

● **Combustors.** The 12-cell type combustors, 4½ in. in diameter and 3 ft. long, have heat releases of approximately 1.2 by 10^6 Btu. per hr. per cu. ft. per atmosphere. Their casings are made of carbon steel pipe with a bellows type expansion joint welded to one end and tapered flanges welded to both ends. The flame tube is made of chromium-nickel alloy sheet rolled into circular sections that are spot-welded together. Alternate sections are corrugated to provide sidewall cooling.

The No. 6 (bunker "C") fuel oil is injected through air atomizing spray nozzles, held in the end plate of the flame tube. These nozzles maintain good atomization at low fuel flows. After the oil is ignited the flame is self-piloting, i.e., there is a primary combustion zone within the flame tube to which only a part of the air is admitted and in which a flow reversal is created. In the rest of the combustor the secondary or dilutant air that surrounds the flame tube is mixed with the hot gases from the primary combustion zone. Axial rows of holes in the flame tube have been found to be the most effective in mixing the cold and hot air streams. In this way the cold gases are able to penetrate effectively to the center of the flame tube, giving very satisfactory temperature distribution at the discharge.

Ignition of the No. 6 (bunker "C") fuel oil is accomplished with acetylene igniters. They are constructed with an outer casing that screws into the combustor casing. Within this outer casing a flame tube, containing a "Monarch" nozzle with the core removed, extends through the combustor casing and the main flame tube into the primary combustion zone. Acetylene gas is piped to the "Monarch" nozzle at a difference of 2 psi above the compressor discharge pressure, and a spark plug is used to ignite it. An igniter has also been developed to use No. 3 furnace oil instead of acetylene gas.

Twelve combustors were used to expedite full scale component testing with available facilities.

● **Gas turbine.** The gas turbine itself consists of eight stages designed for equal heat drop over the stationary and rotary blades at the mean diameter.

The shaft seals used are all of the

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labyrinth type, and the journal bearings are pressure-lubricated sleeve type.

Blading is made of cobalt-chromium-tungsten alloy by the precision casting method. The rotating blade is tapered and twisted and has a serrated root machine in the base. This machining is accomplished with a form type grinder that in turn is dressed with a crushed wheel. The stationary blades are also tapered and twisted and have a single "T" type fastening that is machined by using a carbide tool. All the blading is unshrouded and profiled at the tip.

The rotor is machined from a solid forging of stabilized 19-9 stainless steel, the main section being 14½ in. in diameter and 24 in. long. This was the largest forging ever made of this material at the time and a number were rejected before a sound forging was procured.

The cylinder is made of stabilized 19-9 stainless steel into which are cut grooves for holding the stationary blading. The design was made as nearly symmetrical as possible. The horizontal flanges have been eliminated and the vertical flanges on the inlet end have been slotted to minimize the effect of thermal distortion on the cylinder walls due to rapid temperature change.

All bolting is made of Westinghouse K-42-B material. For the horizontal bolting, sleeves are used to eliminate the need of a flange and to increase effective bolt length. The bolting problem is difficult, for the gas turbine must operate over wide temperature ranges and must be capable of taking instantaneous changes of from 700°F. to 1350°F. in going from no load to full load. The design used has proved entirely satisfactory to date.

The turbine is positioned with suitable mechanical hinges arranged to allow for rapid thermal changes while still maintaining proper alignment with the rest of the machinery.

● **Diffuser and elbow.** A diffuser and elbow are used to recover a part of the leaving velocity energy and to turn the gases with a minimum of energy loss. At full load the exhaust velocity from the turbine is approximately 500 ft. per sec. and a substantial portion of this energy is recovered by the diffuser.

● **Gear.** The gear is a single reduction double helical type. Of particular interest is the pinion, which is made of an alloy steel and has 20 hobbed, flame-hardened, ground teeth. This type of gearing is similar to that employed on the Pennsylvania Railroad geared turbine locomotive, which has proved successful in actual road service. The experience gained from this gear design points the way to designs carrying twice the load without any appreciable change in weight or size. The gear has all pressure-lubricated sleeve type bearings.

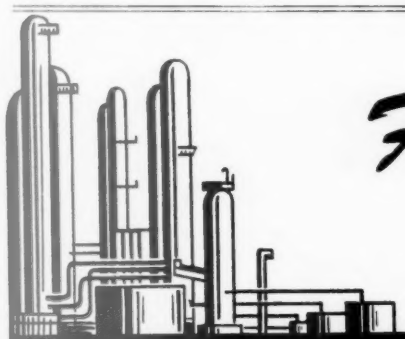
Mounted on the reduction gear is a ½-hp. turning gear motor that drives through a worm and wheel to a spur pinion that in turn drives the gear on the main pinion shaft. This keeps the set turning to avoid thermal distortion of the rotating parts at shut-down and enables quick starting at any time.

● **D-c. generator.** A double-armature d-c. generator, operating at 1200 rpm absorbs the useful power. The d-c. type generator provides a loading device with a very wide operating range. This offers an excellent means of testing the set and developing the proper controls.

● **Silencers.** To reduce noise, silencers were installed on both the inlet and exhaust. The inlet silencer was designed with 12 openings, 7¾ in. by 9 in. by 40 in. long, whereas the exhaust silencer has 16 such openings. Both were lined with sound absorbing fire brick.

● **Test setup of the new gas turbine.** In the test setup two water rheostats are used to absorb the power output of the d-c. generator. Suitable instrumentation has been provided to measure accurately, the overall performance as well as that of the component parts. Motor-driven, geared-type lubricating and fuel-oil pumps are used. Diaphragm type control valves are used in the fuel system and are arranged to provide flexibility in testing fuel controls.

● **Operating experience to date is promising.** Although the testing of this unit is not yet completed, it appears that it will meet satisfactorily its expected performance. Starting tests have been completed that have shown that with 80-kw cranking power the unit can be brought from standstill to operating speed in one minute. If 50-kw is used the time is increased to about 1½ min. ★★



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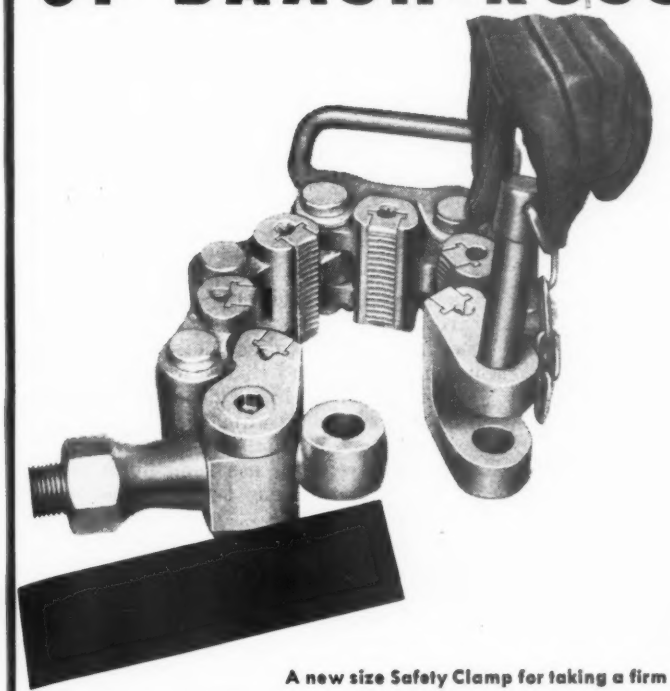
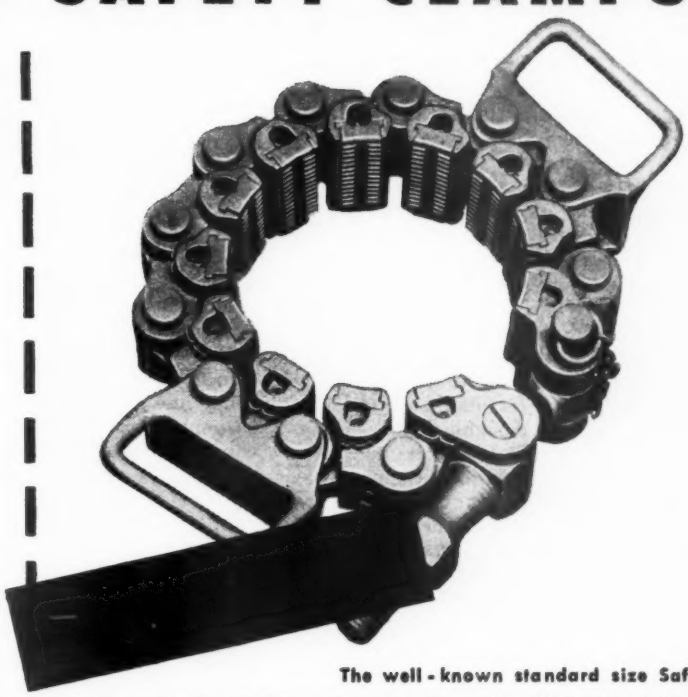


A new size Safety Clamp for taking a firm non-slip grip on Tubing and other small diameter pipe from 1 5/16" O. D. to 4½" O. D. inclusive.



The well-known standard size Safety Clamp for taking a firm non-slip grip on pipe, drill collars, liners, etc. with O. D's from 3¾" to 13⅜" O. D. inclusive.

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QUICKLY APPLIED: To apply either the Tubing or Standard Safety Clamp, simply wrap the flexibly-linked unit around the pipe, insert a pin and cinch tight with the quick-acting wrench. That's all you do to safeguard against dropping flush-jointed tubing, pipe, drill collars and similar equipment down the hole.

NON-SLIP GRIP: As the Clamp is tightened individual spring-loaded slips in each link take a firm initial grip on the pipe. Should the pipe start to drop these slips wedge tighter as the load increases, firmly locking the Clamp to the pipe so that it cannot slip.

WIDE OPERATING RANGE: By simply adding or removing links—a quick, easy operation—both the Tubing and Standard Safety Clamps can be readily adapted to gripping a wide range of diameters. For each link added or removed, a Clamp's range of diameters is increased or decreased one inch, respectively. The Tubing Safety Clamp handles pipe diameters from 1 5/16" O. D. to 4½" O. D. inclusive and the Standard Safety Clamp pipe diameters from 3¾" O. D. to 13⅜" O. D. inclusive.

MANY VALUABLE APPLICATIONS:

There are so many time-saving, labor-saving and trouble-saving uses for the Tubing and Standard Safety Clamps that no rig should be without them. Besides safeguarding against dropping flush tubing, drill collars and other hard-to-handle equipment, use them (1) for providing emergency elevator shoulders when lifting "twist-offs," flush liners, gravel-packed liners, etc... (2) as a grip for pulling line pipe into position, or holding it aligned while welding joints... (3) to simplify the setting of casing and tubing head equipment—and many other uses. Your nearby Baash-Ross representative will gladly give you the details... or write direct.

Development of wellhead equipment*

By **J. E. ECKEL,** *Vice President,* Oil Center Tool Company

DURING the last 20 years the oil industry has seen the definition of the elastic term "high pressure well" undergo rapid revision. In the late 1920's and early 1930's gas well pressures of 1000 to 2000 psi were considered high. We now class such pressures as medium or low. As production depths increased well pressures increased in direct proportion until 4000 to 5000 psi pressures are now routine. At depths below 7000 ft., pressures greater than those due to normal salt water hydrostatic heads are not infrequent and sometimes are as high as 6750 psi. In one recent Gulf Coast completion an abnormal pressure of over 8000 psi was reached.

As the manufacturers of drilling equipment have been faced with the ever-growing demand for equipment capable of penetrating to 15,000 ft., the manufacturers of wellhead equipment likewise have been faced with demand for equipment capable of safely controlling the great pressures encountered at these depths. In this assignment there must be no mistakes, because failure of control equipment in wells of this class may mean loss of property or life or both. As a result, great factors of safety have been the rule in designing this equipment and tests and inspections have become increasingly rigid. Fifteen years ago it was common for an oil operator to purchase the necessary heads and fittings and assemble and pressure test his own christmas tree or in some cases assemble it on the well without pressure test. Today this practice is almost unheard of because extreme pressures and numerous field failures have brought realization that wellhead manufacturers have developed an indespensable service with their specialized equipment for testing trees up to 15,000 psi. It is now generally recognized that the tree must be designed with all operating procedures, methods of pipe, and packer setting or other operating contingencies in mind and then thoroughly tested before brought to the well.

In this paper an attempt is made to trace briefly the development of wellheads during this 20-year period of effort to meet the demand for improved wellhead equipment and methods and also to point out progress in standardization and possibility for further improvement along this line. During this 20 years between 400 and 500 patents have been taken out on wellheads and related equipment. Yet on careful analysis it is possible to break the methods of pipe suspension and seal into relatively few basic classifications, and it is found that most of these numerous patents relate to ingenious variations or improvements of these basic classifications. Of course, in the short time available we cannot examine all these variations, but a glance at a few examples will serve to illustrate the progress made.

● **Types of pipe suspension.** Let us first consider methods of pipe suspension. These may be classified as follows:

1. Threads
   (a) Pipe coupling resting on a support.
   (b) Pipe threaded directly to supporting mandrel.
2. Slips
3. Welding

The familiar Louisiana pattern casinghead is an example of 1 (a), Fig. 1. The early day Berry pattern casinghead is a similar type. Both of these placed the entire casing load on the relatively thin bearing area of the end of the coupling and as depths increased, thread suspension by method 1(b) (Fig. 2) came into use. The supporting area and resistance to radical expansion of this support is much greater.

Method 2, the use of slips for pipe support has been in use for many years as evidenced by the heads used about 1925 or earlier, and illustrated by Fig. 3.

Method 3, welding as a means of pipe support, (Fig. 4) was used extensively in the late 1930's and is still used to some extent, but the use of a weld as a combination pipe support and seal is dependent on field welding practice and has met with great favor as well depths increased and higher strength casing has come into use.

● **Types of seal.** The next factor requiring classification is methods of pipe seal. These may be classified as follows:

1. Threads
2. Welding
3. Packing
   (a) With mechanically controlled compression
   (b) With casing weight compression
   (c) With plastic injection
   (d) Self-sealing.

A thread seal, of course, must also depend on a secondary seal between the supporting element and the wellhead, as illustrated in Fig. 5, an early thread suspension head made about 1928, and Fig. 2, a more modern head. A welding seal may be a combination support and seal weld (Fig. 4), which, of course, requires a secondary seal for the support. The combination support and seal weld is at a disadvantage because it must seal while in shear and any movement of the pipe tends to destroy the seal. It is, therefore, more common practice to separate the support and weld. The welding seal may be used as in integral seal in the same unit with the supporting element (Fig. 6), or may be incorporated in a separate unit above the supporting element (Fig. 7). By this method the seal weld is not in shear because of casing load and its chances of maintaining a pressure tight seal are improved. The seal weld must be made with great care, however, taking into consideration the proper rod for the grade of pipe used, proper preheating of pipe and hanger, and proper cooling of the weld to avoid cracking. The higher the strength and carbon content of the casing the greater the precaution required. Because of the human element and chance for error involved and the adverse conditions and limited space under which welding must be carried out in an oil well cellar, many operators prefer to use some form of packing seal that may be more readily controlled.

As previously mentioned, packing seals are widely used with slip or thread supports and are available in four general classifications. Those with mechanically controlled compression are common and many of the numerous casinghead patents have to do with means for controlling packing seals. Obviously, all the dozens of ingenious methods of controlling packing cannot be shown, but a few representative ones will serve to illustrate mechanical control. Fig. 8 illustrates an early head with simple nut compression of the packing. Fig. 9 shows a ram or movable segment support head with packing controlled independently of ram pressure, and Fig. 10 a tubinghead adapter using the same means of seal and support but with a hanger small enough to go down into the casing when setting screen and packer. Fig. 11 is a ram support head with rams also compressing the packing.

Casing weight compression was in early use as indicated by Fig. 3. Fig. 12 illustrates a more recent model of casing weight compression. A major advantage of casing weight compression is

*Delivered before Houston chapter, American Petroleum Institute, Houston, Texas, August 27, 1946.

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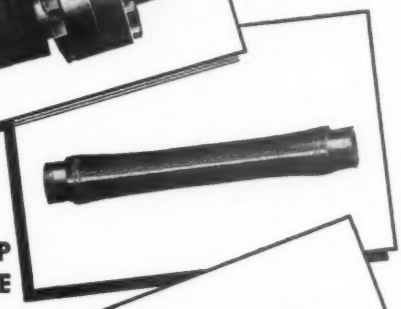

SLUSH PUMP SUCTION HOSE

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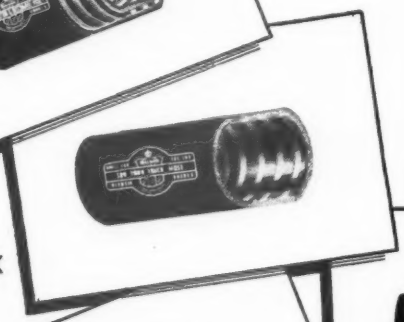
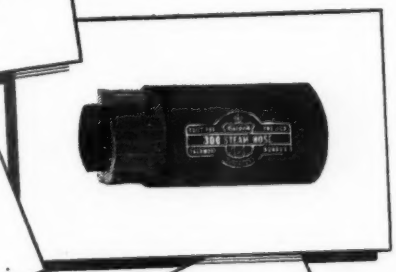


TANK TRUCK HOSE



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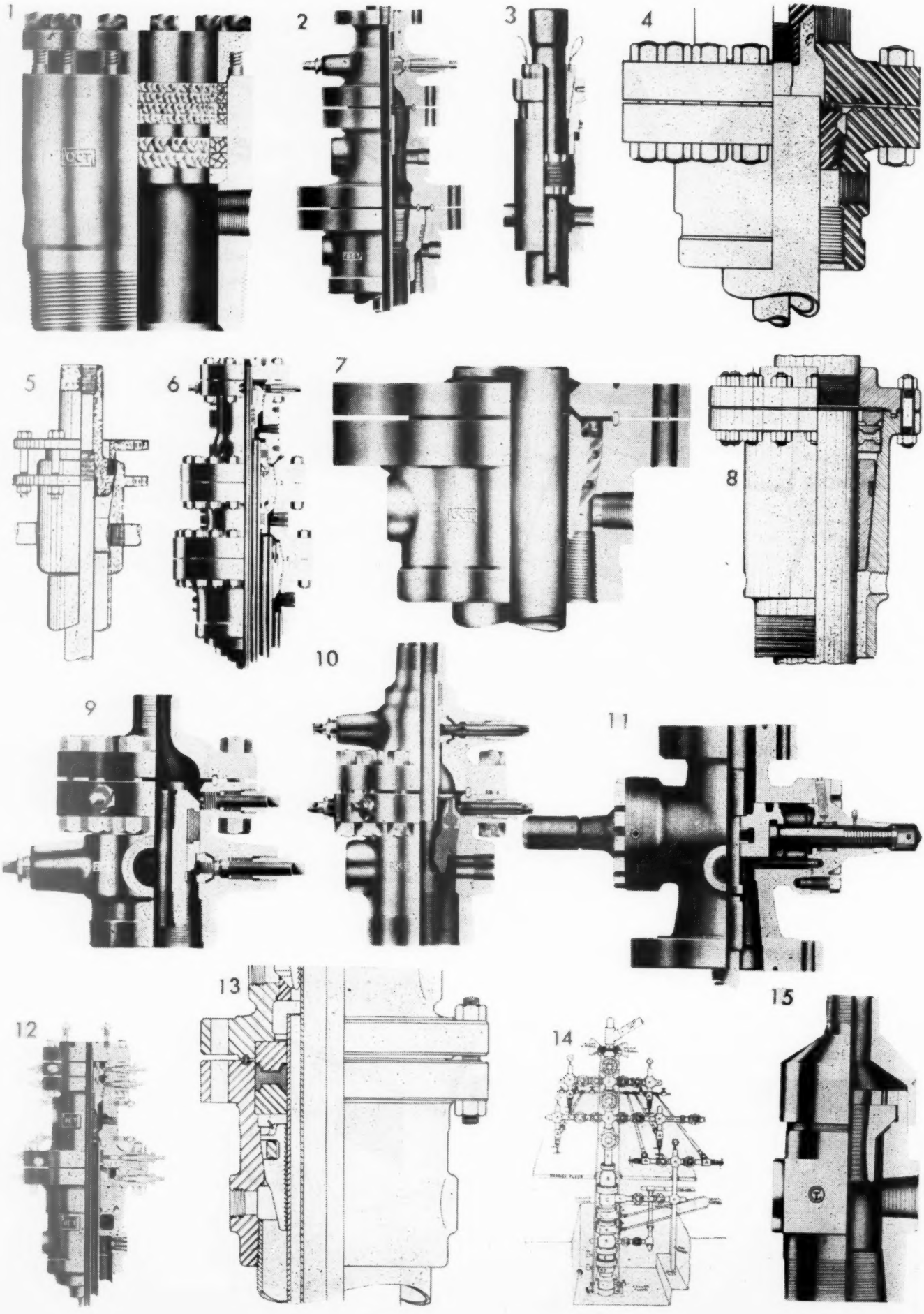
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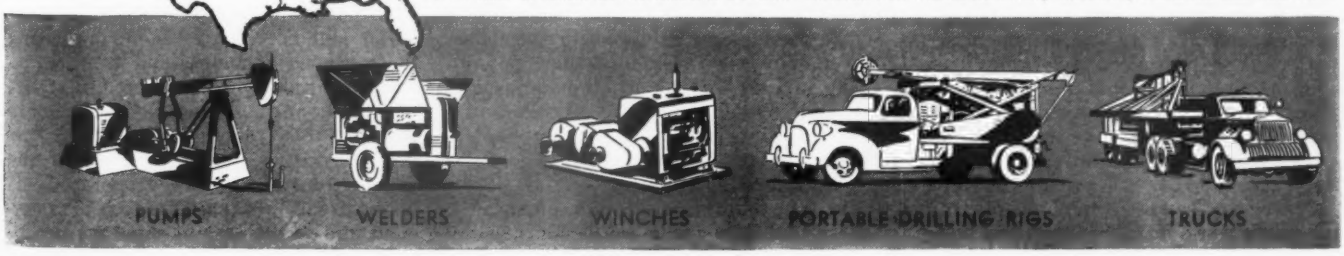


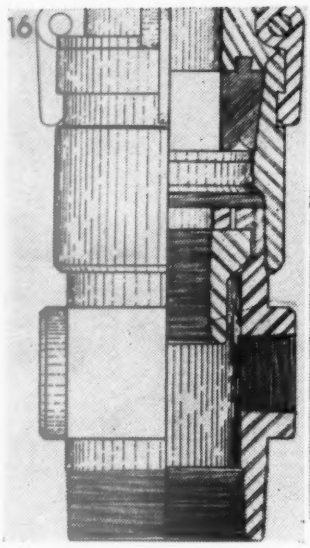


FIG. 16

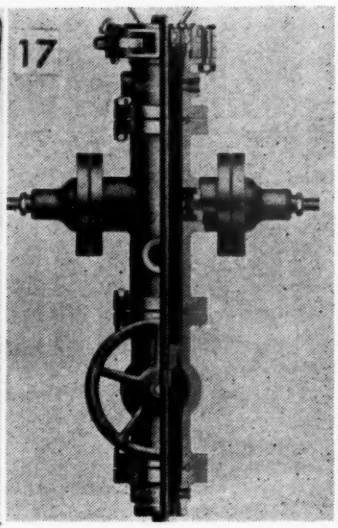


FIG. 17

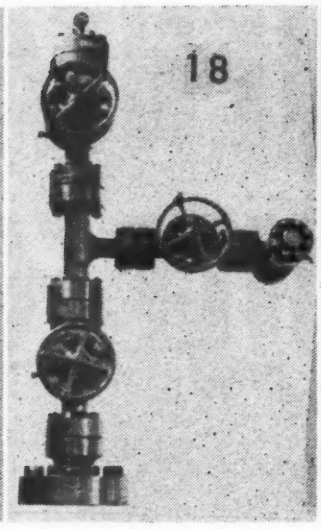


FIG. 18

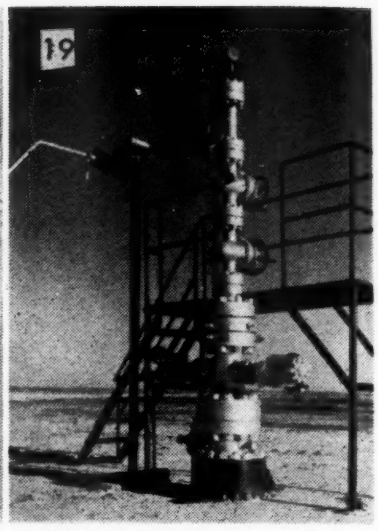


FIG. 19

that a seal is formed as soon as the pipe is suspended and is maintained under constant compression with automatic take up. It should be noted in this model that a combination of casing weight and mechanical adjustment are used, permitting take up of the seal at any time during the life of the wells.

Plastic injection is illustrated by Fig. 11 as a seal around a shaft. A similar seal around pipe is a convenient method of forming a seal with external control. Injection of additional plastic permits correction of leakage during the life of the well.

Self-sealing packings are those such as the chevron lip type that become effective upon the application of pressure. Some types are effective only from one direction and others from two directions. Fig. 13 illustrates a form of the latter. Although in some cases used as a primary seal the most common usage of self-sealing packings is as a secondary seal to permit pressure testing of the primary seal.

● **Installation of wellhead equipment.** In the early development of wellhead equipment little thought was given to prevention of blowouts or pressure control of the well while suspending and sealing the pipe strings. As can be seen in Figs. 1 and 5, early heads provided no means of connecting control equipment above the wellhead as a protection while running and landing casing. The wild wells and famed "gushers" of early fields were the accepted thing and apparently it was not thought possible to maintain the well closed in during the transition from drilling connections to flowing connections. The through bores of the heads were nearly always too small to pass drilling tools (Fig. 1) and in some cases too small to pass even pipe couplings. This meant that the head upon which the pipe was to be supported and sealed must be installed *after* the string of pipe was installed. Consequently, all surface connections had to be removed while "nippling up" and the well left open to the world while installing the head body and pipe support. In many cases the gas sands did not politely wait during the several hours while these connections were being completed.

The first attempts to do something about this condition seem to have come about in the handling of tubing on high pressure gas wells. In these cases a master gate and sometimes a blowout preventer were placd *below* the tubinghead while drilling-in the well and left in place while running tubing. Of course, the master valve could not be removed after the tubing was landed and must remain in position during the life of the well. Fig. 14 represents an installation of this type, which was common about 1930 in high pressure fields such as Oklahoma City or Kettleman Hills in California. But the master gate was useless with tubing hanging through it and tubing retractor was developed to provide a means of parting the tubing at the master gate in case it became necessary to close it. Because of the excessive investment left on each well in the form of the large master gate and auxiliary equipment a more simple arrangement that could be removed when it has served its purpose was in demand. Fig. 15 shows a head developed about 1930 to meet this need. This head was full opening, and while drilling a master gate and blowout preventer were attached to the male thread at the top of the head (Fig. 16). The well was then drilled-in, tubing run, and the hanger lowered through the control equipment. The hanger was locked down by passing the lock nut through the control equipment. After sealing the tubing the master gate and preventer were removed and the christmas tree installed. Thus the master gate and blowout preventer were salvaged for use elsewhere. This method gained some popularity in East Texas and other fields in the early 1930's, but the problem of breaking out an 8⅝-in. master valve thread repeatedly without injury to the thread retarded its progress. About the same time blowout preventer manufacturers that also made wellheads developed a similar arrangement using their own specially drilled flange on both heads and preventers; but this required a special flange or master valves made by other manufacturers. The American Petroleum Institute then tackled the problem of ring joint flange standardization and the method of flange well control shown in Fig. 17 came into general use. After landing tubing the flanged master valve and preventer can be readily removed and a flanged christmas tree, as shown in Fig. 18, installed. As both wellhead manufacturers and blowout preventer manufacturers changed to API flanges, control equipment became adaptable to any make of wellhead and this method of well completion became widely used throughout the world. Thus it can be seen that simple standardization of flanges had a much more far-reaching effect than merely making flanges uniform in dimensions. Although no specific data are readily available, it may be safely said that the frequency of blowouts took a decided drop as ring joint standards came into general use.

Figs. 12 and 19 show present day wellhead assemblies and christmas trees with all-flanged connections, reduced pressure area seals, compact construction, and many other desirable features. Contrast the complexity of the tree in Fig. 14 made for 2000-lb. working pressure with the one in Fig. 19 on a well with 6750-lb. shut-in pressure.

There remains, however, much that can be accomplished along the line of standardization of wellhead equipment. Although, as previously mentioned, many patents exist on methods of pipe suspension and seal and these parts are therefore not subject to standardization, the outlet and flow connections comprising the wellhead and christmas tree assembly are subject to some degree of standardization, and considerable money could be saved both operators and manufacturers by such standardization. At the present time nearly every operator has his own special christmas tree arrangement and in the case of some major op-

"Our Conditions Are Different"

Of course they are—no two wells ever drilled were just the same. But here's something to remember . . . a fact proven times without number in the Mid-Continent, on the Gulf Coast, in California, in *every* major oil area in this country . . . and that is,

under ANY Conditions, you can call your shots . . . and McCULLOUGH will put the shots where they count!

RUN ON DRILL PIPE

A method often used when well pressures are high and it is considered necessary to have absolute control at all times, before and after perforating.

ELECTRICAL FIRING

Gun run from completely equipped service truck, or on your own conductor cable. As in all McCullough gun-perforating jobs, all shots are fired at the same instant while the gun is at rest at the exact depth you want it. There are no electrical circuits in the gun, so it is only a matter of a few seconds to switch the electrical top assembly to another gun—no long waits between runs.

MECHANICAL FIRING

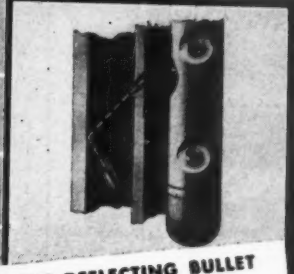
By using the mechanical firing top assembly all McCullough guns can be run on a wire line, either our own or your sandline or drilling line, and detonated by go-devils dropped when the gun is in place. Positive in action, perfectly safe, this method gives all the advantages of McCullough gun-perforating to a wide range of jobs under many different conditions.

RUN ON WIRE LINE

In extremely high-pressure wells, where blowout preventer packing is necessarily so tight that the weight of the gun cannot pull an ordinary line through it, or when there is danger of the large line being blown out, McCullough successfully perforates by running the required type of gun quickly and safely through a special packing head on a piano-wire measuring line—thin and smooth but tremendously strong.

RUN ON TUBING

Using the same set-up as for drill-pipe, or with the addition of a packer between slotted pipe and the production string, high-pressure wells are successfully perforated with a McCullough regular type or sectional gun firing as many shots as are needed to cover the productive zones.



THE DEFLECTING BULLET

For regulating gas/oil ratios, for freeing stuck pipe, for establishing circulation—for any job where it is necessary to punch a clean hole through drill pipe or tubing without damaging the surrounding casing, McCullough has developed an exclusive feature to do the "impossible" . . . the McCullough Deflecting Bullet. The "bullet which turns a corner" has been used in hundreds of jobs.

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erators a different style of tree and head arrangement is used in each field in which he operates. Each quotation and each order are special and each tree is tailor-made. This results in a greatly increased operating cost to wellhead and tree manufacturers, which in turn must be passed on to the equipment user. My company, for example, maintains a staff to handle quotations alone that consists of a draftsman and parts lister, a price lister, a checker, and a blue-print operator, continuously turning out new assembly quotations on trees that are similar but never quite the same. Our file reflects nearly 600 christmas tree variations quoted or sold during the last two years. Loss of time is appreciable in the shop resulting from continuous variation and careful checking to avoid errors that could be eliminated if more units were turned out to uniform specifications.

After all is considered, casing programs are no longer numerous and well pressures are now grouped into four general classes. Methods of well completion, packer settings, etc., are approaching some uniformity. It would, therefore, seem that each operator might set up diagrammatic tree layouts grouping his casing programs and pressure needs into general groups and yet so designed that any make of head with a method of pipe seal and suspension meeting his approval may be used. Such a diagrammatic drawing is used by one major oil operator for placing his orders. Each column of figures on the drawing is for a specific casing program and pressure. The generalized drawing has each component part designated by letters and each column has numerals opposite these letters. These numerals in turn refer to a parts list that describes in detail the specifications of the part required for that particular pressure and casing program. The casing hanger has optional numbers permitting the field to specify the type of suspension and seal preferred. Thus to order a tree for a specific job the field man need only specify the drawing number, column number, and state his hanger option. The christmas tree manufacturer, having a copy of this schematic drawing, can readily fill the tree order with a minimum of confusion.

A similar drawing is made for the upper section of the christmas tree.

It is suggested that oil operators consider a study of standardization of their wellhead and christmas tree needs throughout their operations, with the thought of making a single type of arrangement cover as many operations as possible. After each operator has thus boiled his requirements down to a minimum of variations it is to be hoped that an API committee might then work toward industry-wide standardization. It is, of course, understood that API policy does not permit standardization to limit manufacturer's freedom of design improvement, and that patented methods of pipe suspension, seal, chokes, and so on could be fitted into the generalized layouts so standardized.

★ ★ ★

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All "ARMSTRONG BROS." Pipe Cutters, "Barnes Type", "Saunders Type" and "Drop Forged" are improved tools. Pins and rollers are hardened tool steel; will hold their alignment and cut pipe off squarely. They have thin *knife blade* cutter wheels of alloy steel that cut easily, leave minimum burr, and hold their keen edge.

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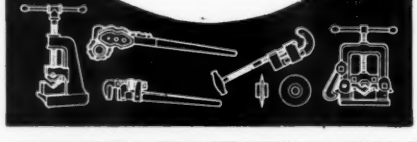

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It costs only a few cents to use RECTORSEAL on thread connections to make them permanently leak-proof. This precaution when making up connections will prevent such costly operations as pulling strings of pipe, taking up drilling and flow lines, breaking out christmas tree and separator connections, to stop leaks which develop in connections not properly protected.

RECTORSEAL not only costs little to use, but is easy and quick to apply. It can be swabbed or brushed directly from the container.

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NEW EQUIPMENT

(1) Control system

A new electro-hydraulic governing system for diesel-electric drives, readily adaptable for locomotives, ship propulsion, mobile and stationary power plants, oil well drilling rigs, and industrial uses where diesel-electric drives are employed, has been developed by the General Electric Company.

Designed especially for power plant load control, the salient features of the system are exceptional speed control with good stability, highly responsive to changes in generator demand and engine ability, engine protection, remote control, and multiple-unit operation, according to G-E engineers.

Speed measurement is performed by an engine-driven a-c tachometer generator whose output voltage is proportional to speed. Speed is maintained at pre-set values, by feeding the speed indication to a hydraulic servo-mechanism that controls the engine fuel and generator excitation, and makes possible full utilization of the engine without danger of overloading.

The system operates stably over a wide speed range, and permits the use of the lowest possible engine speed commensurate with power requirements. The use of feedback from the electrical load allows the control to anticipate the speed changes that would be produced by changes in generator demand, and therefore minimizes transient regulation.

Engine protection safety features are built in this new governing system. Overspeed protection is provided by an overspeed trip switch that automatically cuts off the fuel supply when the engine overspeeds. If the engine lubricating oil pressure drops to the danger level, a short-circuiting switch drops the engine speed automatically to idle. Similar type switches, functioning with the same end result, operate at dangerously high temperatures or on occurrence of a ground in the main power circuit.

Remote control in this system is readily achieved. The manual and automatic controls may be placed at any desired distance from the prime mover. Speed modulation can be infinite or by definite steps as in throttle notches. The engine-speed indicator is remote from the fuel control. Multiple-unit operation, as in the case of diesel-electric locomotives, is readily accomplished.

(2) Hilton Ringuard

The Hilton Ringuard, a flexible insert liner with spring steel core, provides, according to its manufacturer, The L. D. Hilton Company, Houston, Texas, complete protection to metal ring joints against corrosive and abrasive actions. An additional value incorporated in its design is the auxiliary pressure sealing feature. In this function the action is automatic and instant at the slightest leakage of pressure past the metal to metal sealing point between ring joint and flange faces.

In the development of the Hilton Ringuard the trial and error route was followed. Experiments were conducted on the assembly floor and test racks of machine shops together with actual field tests. The results of these tests were the determining factors governing its design, the manufacturer states.

Outer Ringuards to protect ring joints against salt water corrosion are also available.

The equipment is available for all sizes of API-Ring Joints.

(3) Lincoln electrodes

A new electrode that greatly simplifies the welding of high sulphur, free-machining steel and of certain high tensile, low-alloy steels, is announced by The Lincoln Electric Company, Cleveland, Ohio.

The new Lincoln Electric electrode, known as "Shield-Arc LH-70," has a low-hydrogen, low-moisture coating and is designed for use with d-c polarity, as the welded tensile properties are 70,000-80,000 tensile strength and elongation is 25 to 30 per cent. Welding currents used are high in comparison with other all-position-type electrodes, it is stated. For example, approximately the same current is used with $\frac{5}{32}$-in. LH-70 as with $\frac{3}{16}$-in. size in other all-position electrodes. The range is: $\frac{1}{8}$-in., 100 to 135 amp.; $\frac{5}{32}$-in., 140 to 190 amp., and $\frac{3}{16}$-in., 180 to 250 amp. A rather short arc is recommended.

"Shield-Arc LH-70" makes possible a weld in less time, according to The Lincoln Electric Company, on a number of types of steel and will open the way for a much wider use of these steels than heretofore. Preheating of high-tensile, low-alloy steels can now be eliminated or largely reduced; welds of exceptional toughness can be made on high carbon and other steels that tend to show underbead cracking when welded with the usual type of electrodes; welding high-silicon electrical sheet steel is highly practicable with the new electrode and high sulphur steels can be welded as readily as low sulphur mild steel.

The electrode comes packed in 50-lb. containers, sizes $\frac{1}{8}$ in., $\frac{5}{32}$ in., and $\frac{3}{16}$ in. in diameter by 14 in. in length.

High-carbon electrodes for building up worn steel parts by welding with low-voltage a-c transformers, as well as d-c, are also announced by The Lincoln Electric Company.

The new electrodes are designated as "Hardweld 50 A.C." and "Hardweld 100 A.C." to differentiate between "Hardweld 100" and "Hardweld 50," which operate only on direct current. They open a new field in the application of a-c welders to produce a dense, tough surface of moderate hardness to resist shock and abrasion.

The new electrodes, which have a heavily extruded shielded-arc-type coating, produce flat, smooth beads and the deposits can be hot-forged, it is stated.

"Hardweld 100 A.C." has a hardness of deposit on straight carbon steel when allowed to cool naturally of 20 to 45 Rockwell C. The exact hardness depends upon rate of cooling and carbon content of the steel welded. "Hardwell 50 A.C." on straight carbon steel has a hardness of 20 to 35 Rockwell C. Deposits may be further hardened by water quenching from approximately 1500°F. or by flame hardening.

The sizes and current ranges, either a-c or d-c, for "Hardweld 100 A.C." are: ⅛ in., range 70 to 110; $\frac{5}{32}$ in., 105 to 170; $\frac{3}{16}$ in., 145 to 230, and ¼ in., 215 to 350. The primary color is brown and secondary color is blue, under the NEMA color code.

There are two sizes of "Hardweld 50 A.C.," $\frac{3}{16}$ in. and ¼ in. with the same current range for each size as "Hardweld 100 A.C." The primary color is brown and there is no secondary color.

(4) DBH unitized block

Baash-Ross unitized blocks have become widely known througout the oil industry for the advantages they offer on portable rig operations, production jobs, and similar work.

Left—Baash-Ross "DBH" unitized block with hook. Right—Unitized block with link adapter.

Showing how "DBH" block is hinged and can be readily opened for maximum convenience and speed in laying lines in place.

These blocks combine—in one compact unit—both a traveling block and a free-swiveling hook or link adapter connector, thus eliminating the space usually wasted by bails between these two units and providing an unusually compact and convenient block assembly, according to the manufacturer.

Now, through development of the new DBH unitized block, another convenience has been incorporated into this equipment. The DBH block is so designed that by simply pulling one pin the entire block opens to apply the lines in the sheaves. Just lay in the lines, close the block, replace the pin—and the block is ready for use!

This new hinged construction simplifies all types of rigging-up operations. Instead of having to reeve lines through the block or remove the guard to expose sheaves, simply pull a pin, open the block and lay the lines in place. On rig-to-rig production work the operator can leave the lines hanging in the derrick between jobs. When production work is necessary, the crew simply lays the loops into the block, closes it, and the crew is ready to work in a fraction of the time ordinarily required for reeving the line. It not only saves time and saves work, but is also a definite safety advantage because there is no need for risky crown operations to reeve the lines; and there are still other ways this new Baash-Ross development speeds and simplifies rig operations, the makers state.

The Baash-Ross DBH unitized block is available with either a built-in hook connection or with a built-in link adapter for holding the elevator links. By using the link adapter and a Baash-Ross swivel bail adapter on the swivel, the operator can run pipe and support the drill string with the same elevator assembly, thus simplifying operations and saving valuable derrick space.

In addition to the two basic types of connectors, DBH unitized blocks are available with 1, 2, 3, or 4 sheaves in a wide range of sheave diameters and with load ratings from 30 to 150 tons. On all units the free-swiveling hook or link adapter can be locked quickly in any one of eight equally-spaced positions whenever desired.

(5) McFarland units

No prime movers of any description are required to operate the hydrostatic testing units and pressure pumps recently announced by McFarland Manufacturing Corporation, Houston, Texas. The units, available in two sizes, operate on water, air, gas, or steam pressures and discharge liquids or gases at pressures directly proportional to operating pressures.

McFarland Units are double acting reciprocating pumps, available with or without booster attachments. Main castings and most parts are of high quality, high strength aluminum bronze with great resistance to corrosion, erosion, and abrasion. They are non-sparking and may be safely used in refineries and other industries where fire and explosion hazards are great, the manufacturer states. The units are of light weight and can be operated in any position, under water, or in hazardous locations. They are entirely free of vibration and need not be fastened down when operating.

With the 6-5¼ unit with booster, discharge inlet pressure ratios up to 200/1 are obtained. For instance, a discharge pressure of 12,000 psi is obtained with this unit, operating on ordinary city water pressure at 60 psi. Other ratios are obtained by changing the cylinder and piston in the booster. The 6-5¼ unit, without booster, operates at a 4:25/1 ratio. The small 3-2½ unit operates at ratios from 2/1 to 4.5/1. One outstanding feature is that all discharge pressures are confined to the booster—the highest pressure to which the body is subjected is the input operating pressure. Desired pressures are maintained automatically once they are reached.

McFarland units are being used for hydrostatic testing of pressure vessels and equipment, for hydraulic press pumps, blowout preventer standby, chemical proportioning, high pressure cleaning and wash down, spray painting, insecticide spraying, and other applications where liquids or gases must be discharged or transferred under low or high pressures, in low to medium volume.

McFarland units are available for immediate delivery.

(6) Hydraulic pump

A new hydraulic pump, the Aldrich-Lytle Hydropneumatic Power Unit, was among the products introduced at the 17th National Power Exposition in New York on December 2. This unit, manufactured by the Aldrich Pump Company, Allentown, Pennsylvania, is a simplex, double-acting hydraulic pump—powered by air. Engineered and built to provide low volume, high pressure service, it is simple, economical, and highly efficient, according to the manufacturer. Troubles with "wire drawing" through relief valves, as well as the need for constant adjustment, are entirely eliminated since the pump stalls when the desired hydraulic pressure developed corresponds to the air pressure used, the makers assert. Pump delivery is not displaced through a relief valve—the relief valve on this pump being situated in the air supply line.

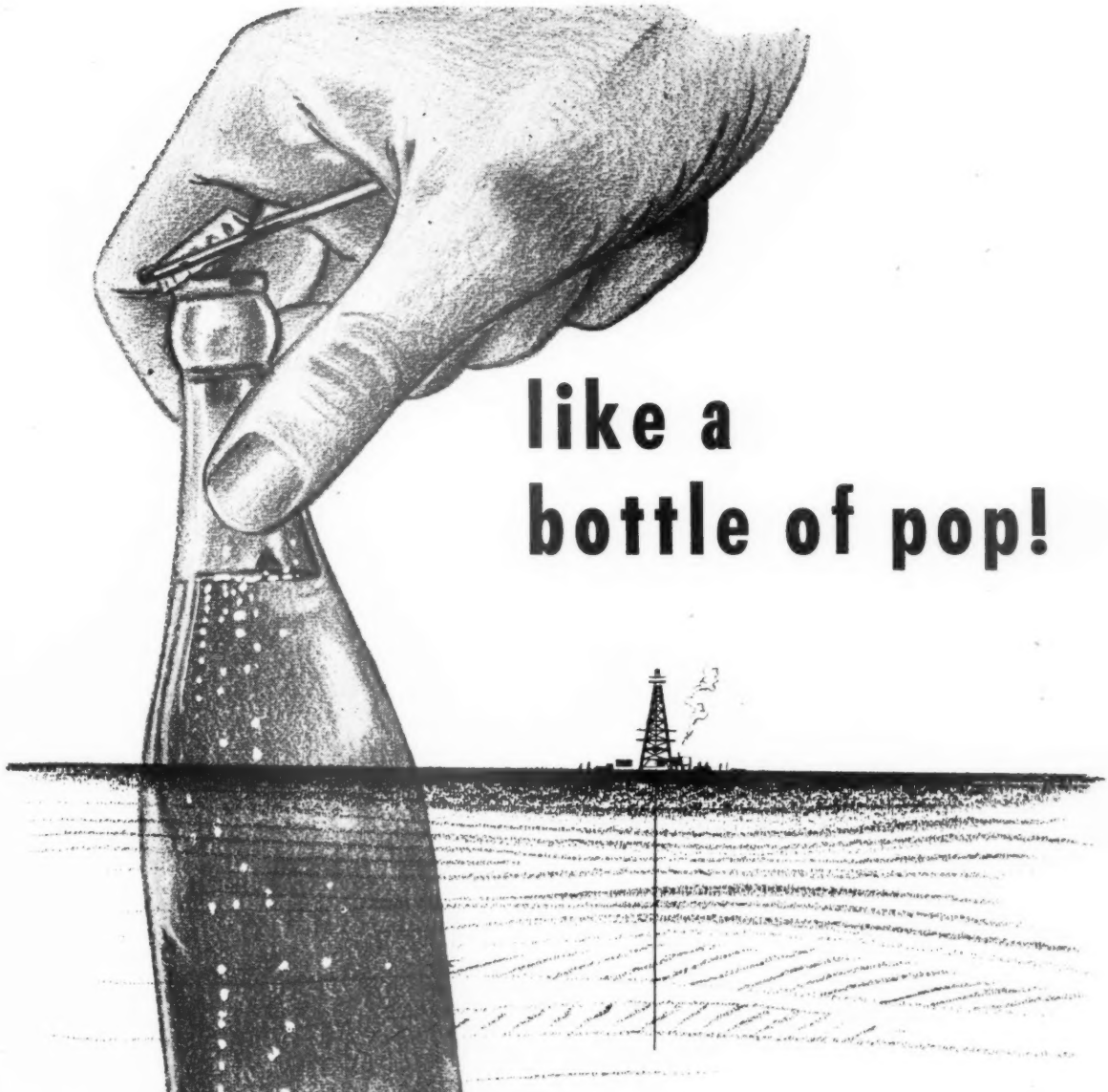
Power is derived from plant air pressure or, if this is unavailable, from a small commercial air compressor. Various pressures can be obtained by simple adjustment of the self-contained air pressure reducing valve. Hydraulic pressures can be maintained without the need for control devices or bypass valve, it is stated.

The Aldrich-Lytle Hydropneumatic Power Unit is operated by a vertical double-acting air cylinder and piston that is direct-connected to the upward-acting pump plunger and yoke-connected to the downward-acting plunger. The pump cylinders are opposed and are of integral construction. On hydraulic demand, the pump starts to operate and continues until total pressures in air and hydraulic sides equalize.

This pump makes possible a small supply of fluid at the desired high pressure—by means of only a small quantity of low pressure compressed air. Being vertical, it takes little floor space, is well balanced, and reduces wear to a minimum. By specifying proper ratio of air piston to hydraulic plunger, hydraulic pressures up to 20,000 lb. can be obtained with a maximum air pressure of only 100 lb. This pump, however, is not intended for use where continuous flow of liquid is required.

(7) Wrought-iron nipples

A. M. Byers Company, Pittsburgh, has announced that wrought iron nipples, both black and galvanized, standard and extra heavy, are now available for delivery in six to eight weeks on large specifications. Increased production of these items at the company's plants, it was reported, has enabled quotation of better delivery schedules.



like a bottle of pop!

Pull the cap off a bottle of pop—watch the bubbles form rapidly and move to the surface.

This same phenomenon, Saturation Pressure,* is encountered when an oil zone is tapped. The reservoir, existing in a natural state of equilibrium, becomes exposed to reduced pressure and gas comes out of solution and [illegible]. Thus, the well flows until energy furnished by gas in solution with the oil becomes less than the weight of the fluid column. Even after the well has been put on artificial lift Saturation Pressure, dependent on amount of gas in solution, *still remains the major factor in moving oil out of the sand into the well bore.*

Many reservoirs have a Saturation Pressure equal to bottom-hole pressure. Some of these, having more gas than will go into solution with the liquid, are found with an original gas zone above the oil. Still others, "undersaturated crudes," have a bottom-hole pressure higher than the Saturation Pressure.

Thus, for maximum recovery the possible variance of production mechanics should be considered of upmost importance in each particular reservoir.

By recommendations developed in the laboratory through accurate Reservoir Fluid Analysis, Core Lab has made maximum recovery through economical methods possible in hundreds of oil and gas reservoirs.

From completion to profit, Core Lab leads in the advancement of Petroleum Reservoir Engineering.

**Saturation Pressure of any liquid and gas solution is that pressure at which the first increment of gas will begin to come out of solution with the liquid.*

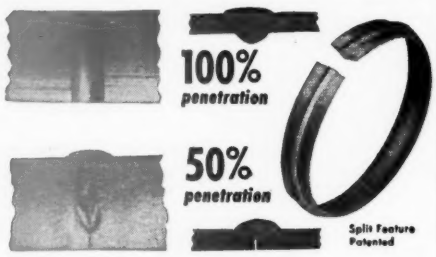
CORE LABORATORIES, INC. ● DALLAS 11, TEXAS

CORE

PETROLEUM RESERVOIR

You can NOW use THIN WALL PIPE with SAFETY by welding joints with WEDGE Split CHILL RINGS

Engineers now SAFELY use thin wall pipe for pipe and refinery lines, by welding joints with the use of WEDGE Chill Rings with the patented SPLIT Feature. This lowers costs and reduces weight. Joints are STRONGER because WEDGE Chill



Rings REINFORCE them, and because you are sure of 100% PENETRATION of the entire circumference of every joint. In case of shock or strain the pipe will fail before the reinforced joints. It is because of such advantages that many engineers have standardized on thin wall pipe for pipe and refinery lines... welding with WEDGE Split Chill Rings.

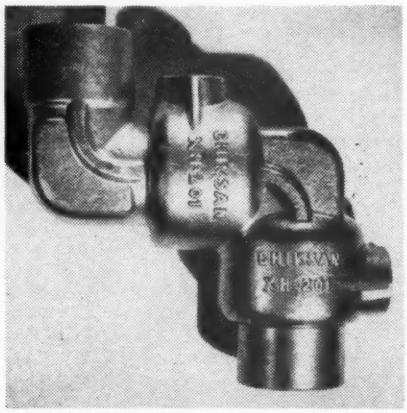
Write for Information

WEDGE PROTECTORS, INC.
3977 Jennings Road, Cleveland 9, Ohio

WEDGE Split CHILL RINGS SAVE MONEY

(8) Chiksan swivel joint

The new Chiksan XH (extra high pressure) swivel joint is built for working pressures of 12,000 psi and provides the same low torque and positive packing seal-off associated with all Chiksan swivel joints since their inception, the manufacturer announces. Rotating members are steel forgings, machined to close tolerances and with flame-harded ball races. Full 360-deg. rotation with low torque takes place on two rows of hardened steel balls that also serve to hold the rotating members together under pre-regulated pressure. The packing element is specially designed for high pressure service and is self-adjusting. As in all Chiksan ball-bearing swivel joints, the new Type



XH employs no bolted flanges, locking rings, or stuffingboxes. There is nothing to tighten or adjust. High pressure lubricating fittings provide for positive lubrication of the bearings. Inside diameter is unobstructed, permitting full flow of liquids, gases, and vapors with minimum friction loss and turbulence. End connections are of the high pressure, tapered thread type. The new Type XH Chiksan swivel joint is recommended by the manufacturer for all high pressure services to 12,000 psi where maximum flexibility, easy turning, minimum maintenance, long life, and maximum safety are essential. The complete Chiksan line of ball-bearing swivel joints also includes more than 500 different types, styles, and sizes for pressures to 300 psi, 1000 psi, and 3000 psi, and temperatures to 500°F. The manufacturer is Chiksan Company, Brea, California.

(9) Microwave spectroscope

Radar waves from 1.2 to 1.6 cm in length have found a new use in a microwave spectroscope developed for the analysis of chemical substances. Like the infra-red spectroscope to which it is analogous, the microwave spectroscope can identify the more complicated molecules such as hydrocarbons without the laborious chemical processes involved in breaking them down and analyzing their various components.

Identification of whole molecules is accomplished by beaming microwaves through the vapor of the substance to be analyzed. Just as all the colors of the visible spectrum except blue and yellow are absorbed by a green screen certain wave lengths of these microwaves are absorbed by those molecules, which they cause to rotate in resonance. Molecules of different substances absorb a different series of wave lengths. Thus for each substance there is a characteristic pattern of absorbtion lines that when projected electronically on a screen present an easily identifiable fingerprint of the vapor under investigation.

The basic elements of the microwave spectroscope as developed by Drs. William E. Good, Donald K. Coles, and T. W. Dakin of the Westinghouse Research Laboratories are an oscillator tube or radar tube, waveguide, crystal detector, oscilloscope, and sweep generator.

Microwaves emitted by the oscillator tube are directed through a rectangular waveguide that contains the sample gas or vapor to be analyzed in a gas cell section that is sealed off with plastic tape. At the far end they are picked up by a sensitive crystal detector that passes the impulse received on to the oscilloscope. For clearer definition of the absorbtion lines the vapors in the gas cell are held to a pressure of about 0.1 mm of mercury.

The oscillator tubes used to obtain microwaves in wave lengths varying from 1.2 cm to 1.6 cm are reflex klystrons tuned by changing the size of the resonant cavity. Several tubes are used to cover the band of frequencies required.

The frequency of the oscillator tube, or klystrom, is swept in synchronism with the horizontal sweep of the oscilloscope tube, and the output of the crystal detector is applied directly to the vertical plates of the oscilloscope so that absorbtion at a particular frequency will be recorded as a vertical deflection of the oscilloscope trace.

Ammonia has been found to have a pattern of 30 distinct absorbtion lines in this region, which is its "fingerprint." Other compounds that have been tagged by this method are water vapor, acetone, cyanogen bromide, and carbonyl sulphide. The limitations of the microwave spectroscope are not yet known, but it promises to be a very valuable tool in the study of molecules and even of the atomic nuclei within the molecule.

(10) Bowser filters

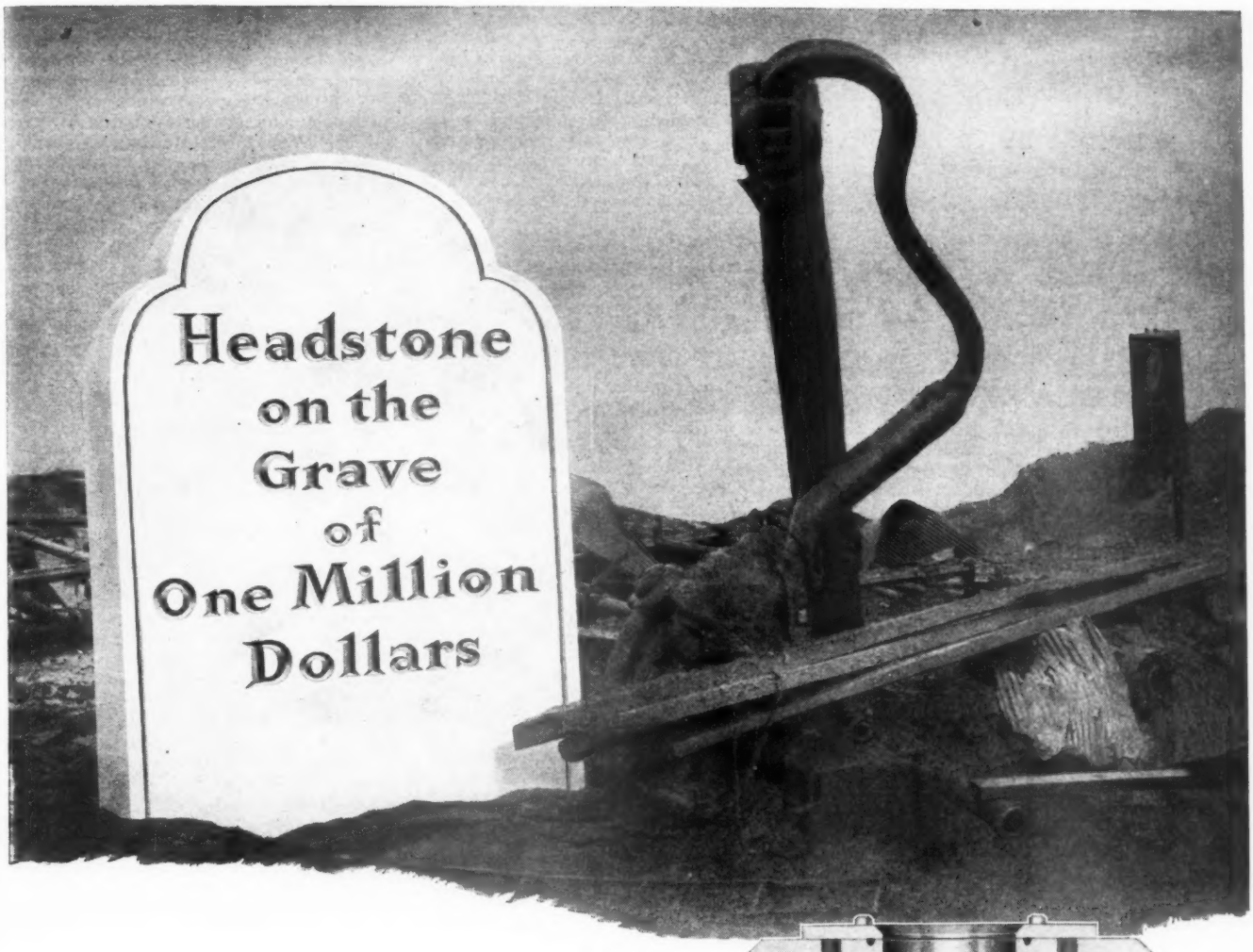
Ten sizes in three new models of expendable cartridge filters are in production at Bowser, Inc., Fort Wayne, Indiana, as announced by Fred S. Ehrman, general sales manager.

The new type filter contains new, replaceable, resin-impregnated, cellulose elements that remove particles as small as 1 micron (0.000039 in.) from liquids with viscosities up to 600 SSU and temperatures as high as 350°F. The cellulose cartridges are completely neutral, contain no chemical bleach, and will not remove additives or inhibitors, or affect the color of the filtered liquid except by the reduction or removal of foreign matter.

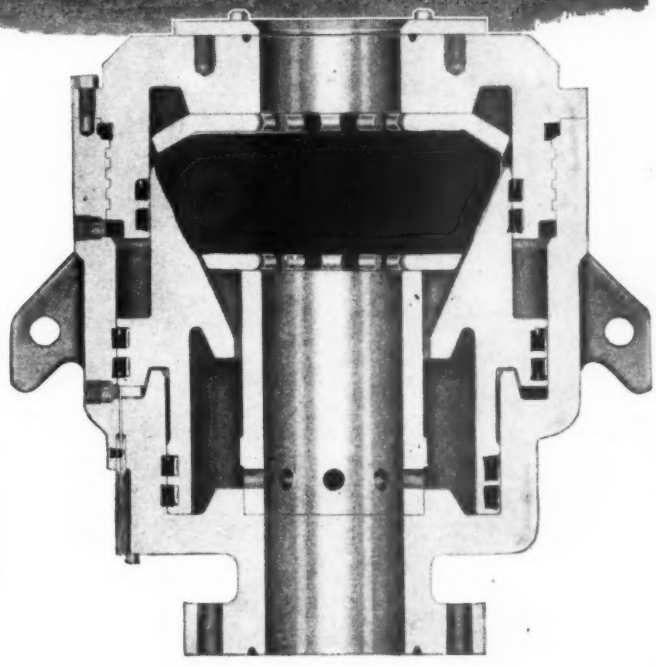
Based on a viscosity of 50-60 SSU oil, the capacities range from 2/5 to 300 gal. per hr. with filtering areas from 0.2 to 100 sq. ft. Pipe connections are located at opposite sides of the filter shells for "in line" piping to eliminate bends and elbows. All units are equipped with vent and drain valves and bolted covers for cleaning and convenience in replacing the inexpensive, expendable cartridges.

The larger models, Figs. 835 and 837, are available in four sizes: 8, 25, 50, and 100 sq. ft. filtering areas. They have proved effective in airport, railway, diesel and bulk plant installations for diesel fuel, lube oil, gasoline, and other petroleum products, according to the manufacturer. Overall dimensions range from 19 to 56 in. in height, and 12½ to 30½ in. in diameter, with pipe connections from 2 to 4 in. conveniently located.

The smallest model illustrated, Fig. 836, is available in six sizes: 1, 1.5, 2, 3, 5, and 10 sq. ft. filtering areas and is recommended



A MELANCHOLY MONUMENT to a moment's loss of control . . . derrick, drawworks and all, lost in a few seconds . . . a calamity which couldn't have happened with the new Hydril "GK" Blowout Preventer. Because the Hydril "GK"—which packs off securely around **any** drill-string or casing-string member, or even on **nothing at all**—gives complete protection every minute from the start of drilling to the setting of tubing, **without changes, additions or adjustments!** Complete details are given in our new Bulletin 946; send for it today. Hydril Company • 714 W. Olympic Blvd., Los Angeles 15, California.



HYDRIL "GK"—THE MOST REMARKABLE BLOWOUT PREVENTER EVER DEVELOPED!

for fuel filtration in stationary engines and wherever petroleum products are filtered intermittently or continuously in moderate quantities. Overall dimensions range from 12⅞ to 40½ in. in height and 7½ to 9½ in. in diameter with pipe connections from ⅜ to 1½ in. on opposite sides of the shells for "in line" installation.

(11) Power take-offs

Large scale production will be begun in 1947 on eight standard models of Davey heavy duty power take-offs, Paul H. Davey, president, Davey Compressor Company, Kent, Ohio, announced recently.

Davey also announced formation of a new truck equipment division to handle power take-off engineering, production, and sales.

The Davey power take-off uses, as its basic principle, an internal and external gear drive, operating as a strong and durable spline (rather than the series of rotating or meshing gears found in transmission type take-offs). Installation is made to the rear of the truck transmission case. The power take-off then becomes an integral part of the driveshaft assembly for transmitting power direct from the truck engine either through V-belts or chain drive.

The eight power take-offs, as announced by Davey, are available in three separate capacities. These are 50, 75, and 100 hp., so designated because of the horsepower that they transmit.

The Model 50 take-off is manufactured in both single and simultaneous drive designs. The latter permits operation of truck, or individual operation of driven equipment, or of both simultaneously.

Models 75 and 100 are manufactured for single drive, simultaneous drive and also for double drive. With double drive take-offs, the truck may be operated alone; either of two pieces of driven equipment may be operated individually, or both pieces of driven equipment may operate simultaneously.

Equipment now being driven by heavy duty power take-offs includes truck-mounted air compressors, generators, gas well bailers, concrete mixers, agricultural machinery, fire-fighting equipment, welders, machine shops, pumps, street sprinklers, home insulation blowers, rock crushers, etc.

(12) Patten process

Many new inventions were perfected during the war, as a direct result of experiments carried on by the Chemical Warfare Branch of our Armed Forces, and now have been adopted and perfected for civilian industry in the advancement of peacetime economy. One of the most phenomenal is the expansion of chemicals in the liners and screens or opposite perforations in the casing of oil wells and chemically heat-treat producing sands under expansion pressure, thereby thoroughly pulverizing any deposit of cement in the hole and destroying any and all corrosion or scale that may have formed. It liquefies drilling mud and will dissolve cement, paraffin, asphaltum or other similar deposits. This expansion of chemical pressure enters the sand after forcing free any obstructions formed in the liners or screens or perforations in the casing, similar to air being forced through a sponge, opening new channels in the sand as well as pressure heat cleaning the old ones. This chemical expansion method also forces the sand back from the liner, loosening it from the formation wall and allowing its free removal. This expansion force shoots only laterally and is of such even pressure and high velocity that there is no tendency to disturb the sand below or above the bottom and top perforation or section of liner and screen treated.

It has been concluded by competent authority from tests made to date that a very small percentage of the liners and screens or the perforations in the casing are open in older wells and that in most cases production is coming from only one-half of 1 per cent to 5 per cent of the original openings, and that in many cases the most productive section of the sand is entirely cut off. This chemical expansion method, known as the Patten Process, opens and cleans liners and screens and perforated sections, together with the above described heat treatment of the sand, and raises production from 2½ to 15 times its pre-treatment recovery and cannot possibly damage the well or any materials used in connection with the well, according to Oil Well Engineering Company, Houston, Texas. It increases the potential on new wells, improves production possibilities of recompletions, and has made many commercial producers of wells scheduled for abandonment.

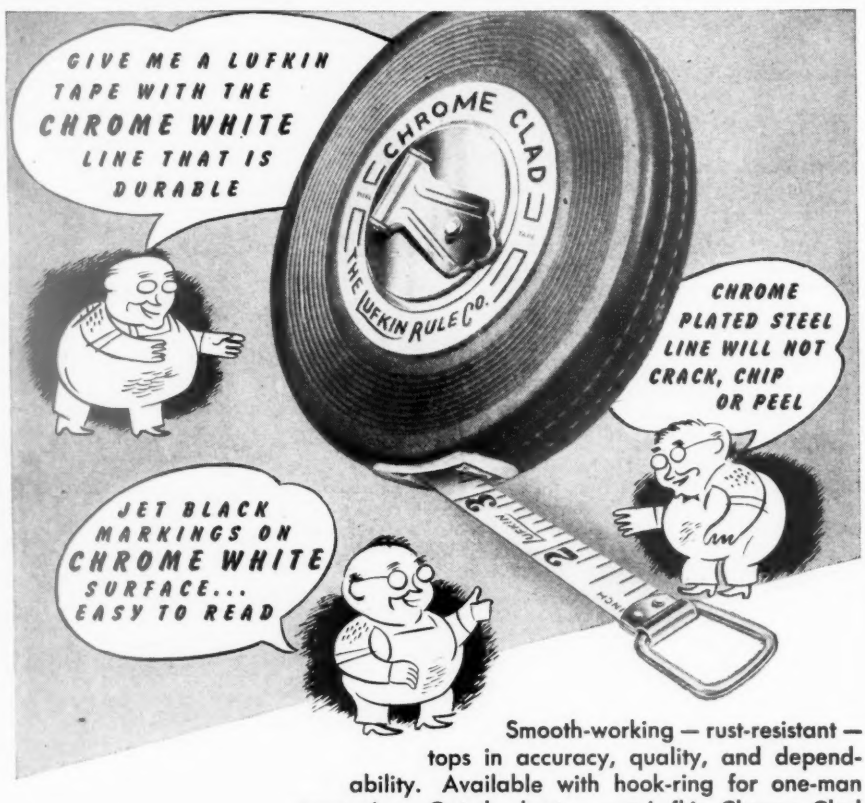
(13) "Pedrifugal" pumps

The Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin, announces a new line of "Pedrifugal" pumps, developed at its Norwood Works, to meet the needs of an unusually wide range of users who require a sturdy, reliable pump of moderate capacity selling at a competitive price.

This new line of cast iron, bronze-fitted, pedestal-type centrifugal pumps comes in three principal sizes: 1 in. by 1 in., 2 in. by 2 in., and 3 in. by 3 in. Capacities are from 10 to 500 gal. per min. at heads from 10 to 100 ft., with power requirements from ¼ to 15 hp. The units are splatter-finished with gray enamel.

"Pedrifugal" pumps are expressly designed for use with Texrope V-belt drives, giving an infinite range of capacities regulated by size of sheaves and power supplied. All the pumps are fitted with impellers of maximum diameter, and variations in capacity are provided by changes in speed through sheaves of larger or smaller diameter.

Small and compactly designed, all sizes of the "Pedrifugal" pumps have essentially the same dimensions. This compactness, together with the fact that the pumps operate in any position, makes the unit well suited to designers of commercial washers and cleaners, large diesels, machine tools, air conditioners, bottling and canning equipment, heat exchangers, and cooling towers.


GIVE ME A LUFKIN TAPE WITH THE CHROME WHITE LINE THAT IS DURABLE
CHROME CLAD
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CHROME PLATED STEEL LINE WILL NOT CRACK, CHIP OR PEEL
JET BLACK MARKINGS ON CHROME WHITE SURFACE... EASY TO READ

Smooth-working — rust-resistant — tops in accuracy, quality, and dependability. Available with hook-ring for one-man measuring. Get the best — get Lufkin Chrome Clad Steel Tapes from your supply house. Write for free catalog.

LUFKIN

THE LUFKIN RULE CO., SAGINAW, MICHIGAN, New York City

RENEWABLE!

TYPE RC

BAROID PIPE TUBING WIPERS

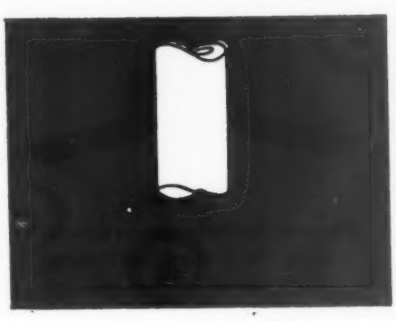
DO A BETTER JOB—LAST LONGER—CUT EXPENSE

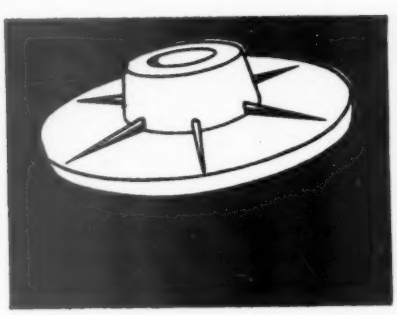
Replaceable-Insert (RC) and One-Piece (S) Types. Replaceable Inserts (Type RC only) make the wiper good for many thousands of feet more pipe at a fraction of the cost of a new wiper. One rim will outlast several inserts.

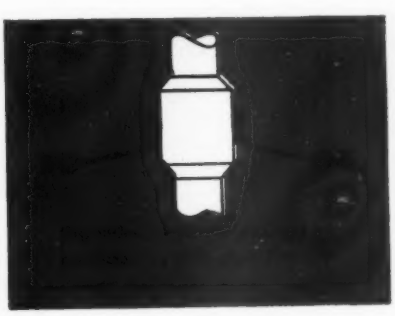
Tapered Center Hole assures greater wiping efficiency and longer life. Raised Center Hub gives greater wiping surface. Strong, Flexible Construction and uniformly blended rubber provide great elasticity and long wear.

Baroid Wipers are products of our Specialties Department which is devoted entirely to designing and producing new and better tools for the oil industry. Baroid Wipers are sold exclusively through Supply Houses. Write for literature and prices.

TYPE S







BAROID SALES DIVISION
NATIONAL LEAD COMPANY
BAROID SALES OFFICES: LOS ANGELES 12 • TULSA 3 • HOUSTON 2

(14) Thread protectors

The Patterson-Ballagh heavy duty thread protector is a new product that has proved its worth since its introduction a few months ago, according to the manufacturer. Made from tough, fabric-reinforced PBX special rubber, it is free from sulphur and other ingredients likely to cause rusting. These thread protectors are designed both to absorb shock and shield threads during handling. They are made in a variety of sizes for both pin end and box end, Standard API right and left hand threads in regular and full hole types. They are easily applied and removed for re-use. Vent and drainage holes permit fluid to flow out but the threads are sealed from exposure and damage.

Patterson-Ballagh heavy duty thread protectors are for use on drill pipe and all heavy items such as drill collars, kelly subs, fishing tools, reamers, and bits, and are quickly and easily applied to prevent damage on all heavy items, it is stated. Their easy use and long life mean great savings in time lost due to tool fitting, re-threading, and replacement, it is asserted.

(15) Flat-belt drive pumps

Several improvements in Blackmer flat-belt drive rotary pumps have been announced by B. L. Gordon, president, Blackmer Pump Company, Grand Rapids, Michigan.

The newly designed combination bracket and belt shifter is of one-piece, heavier construction. It supports the pulley end of the pump shaft in a bronze bushed bearing. The rigidity of the new bracket has been found to prolong bearing life and maintain better shaft alignment.

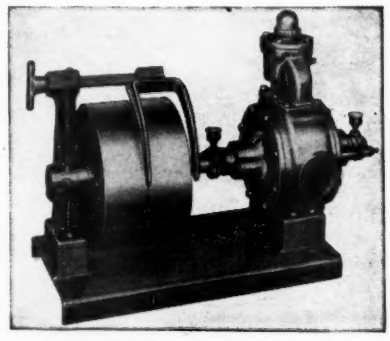
Curved to match the contour of the pulleys, the new belt shifter is said to provide faster and easier belt control than the former shifter, which had straight guides. Decreased headroom requirements are also claimed due to the new design.

A new structural steel base has been adopted and has transverse trusses. It is reported to be lighter in weight and stronger than the previous cast-iron base.

These improvements apply to flat-belt drive Blackmer pumps supplied with removable liners for abrasive liquids or with steam-jacketed heads for viscous liquids. Pump capacities range from 10 to 750 gpm with pressures to 100 psi.

These new features are being incorporated into current production as rapidly as possible and are a part of Blackmer's general program for design improvements in its entire line of rotary pumps.

Flat-belt drive Blackmer pumps are widely used in dry cleaning plants and in industry generally for pumping oils, paints, naphtha, and similar liquids. With sanitary construction and clamp-type head, the same pump is used in canneries and food processing plants.



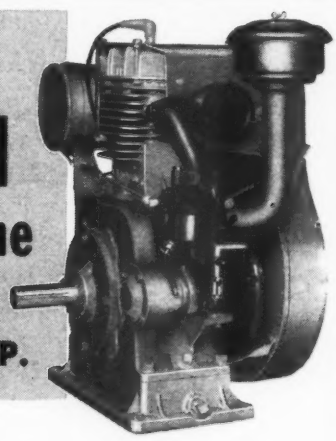
(16) New hose

Something new in the popular-priced hose field is announced by Goodyear Tire and Rubber Company's mechanical goods division.

It's the Black Wing cord line, water and air hose, featuring a body structure based on a new manufacturing principle, according to R. W. Sanborn, manager of Goodyear hose sales.

Horizontally braided, an exclusive method of bonding cover, carcass, and tube together

This HEAVY-DUTY
WISCONSIN
Air-Cooled Engine
IS AVAILABLE IN 4 SIZES . . . 4 TO 9 H. P.



Illustrated above is the Models AEH to AHH series of 4-cycle single cylinder Wisconsin Air-Cooled Standard Engines, to which the following specifications apply:

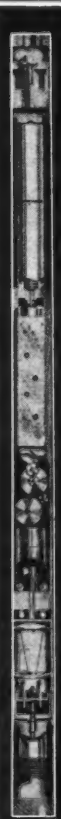
MODEL	AEH	AFH	AGH	AHH
Bore	3"	3¼"	3½"	3⅝"
Stroke	3¼"	4"	4"	4"
Cu. in. Displ.	23	38.2	38.5	41.3
Hp. Range	4-6	5-7	6-8.5	7-9
Weight	130 lbs.	170 lbs.	175 lbs.	180 lbs.

If your equipment calls for an engine within the above power range, it will pay you to give serious consideration to the Wisconsin line . . . noted for rugged, heavy-duty serviceability and thorough-going dependability.

In addition to the engines listed above Wisconsin 4-cycle single cylinder engines are also available in 2 to 4 hp. sizes, and V-type 4-cylinder engines can be supplied in a power range of 13 to 30 hp. Detailed data furnished on request.

WISCONSIN MOTOR Corporation
MILWAUKEE 14, WISCONSIN
World's Largest Builders of Heavy-Duty Air-Cooled Engines

WRITE TO HARLEY SALES CO.
510 Atlas Building, Tulsa, Oklahoma
M & M Building, Houston, Texas
Oil field distributors for Wisconsin Engines and all types of utility units.



Already the best
MULTIPLE SHOT
Oil Well Survey Instrument
but we improved it!

Although the Eastman Multiple Shot has hung up such outstanding records as surveying

1,000,000 FEET
without a failure

progressive Eastman engineers have designed and built a finer, better and even more dependable post-war model and have thoroughly proved its performance in more than a year of actual field service.

Ask for a free demonstration of the new Eastman Multiple Shot in your office or before your engineering staff. See the many improvements—learn the advantages of having a complete Directional Survey made of your well bores from the top to the bottom in a single run of the instrument. No obligation — just call the nearest of our 22 offices.

Eastman
OIL WELL SURVEY COMPANY
GENERAL OFFICES: DENVER, COLO.
Div. Offices: Denver, Long Beach, Dallas, Houston

extra STRENGTH for extra DEPTH

As wells go deeper, your strings must have extra strength to resist collapse and strain on casing joints.

Republic Electric Weld Casing will give your strings that vital quality.

This dependable casing is made by Republic's improved electric resistance welding process, which produces a weld as strong as the wall. High-grade steel flat rolled to close tolerance assures casing that is consistently uniform in size, wall thickness, concentricity and diameter.

This uniformity assures threads with extra pull-out strength, because they have the same amount of metal under the roots at all points in the circumference.

Be sure your strings have the extra strength needed for extra depth by demanding Republic Electric Weld Casing.

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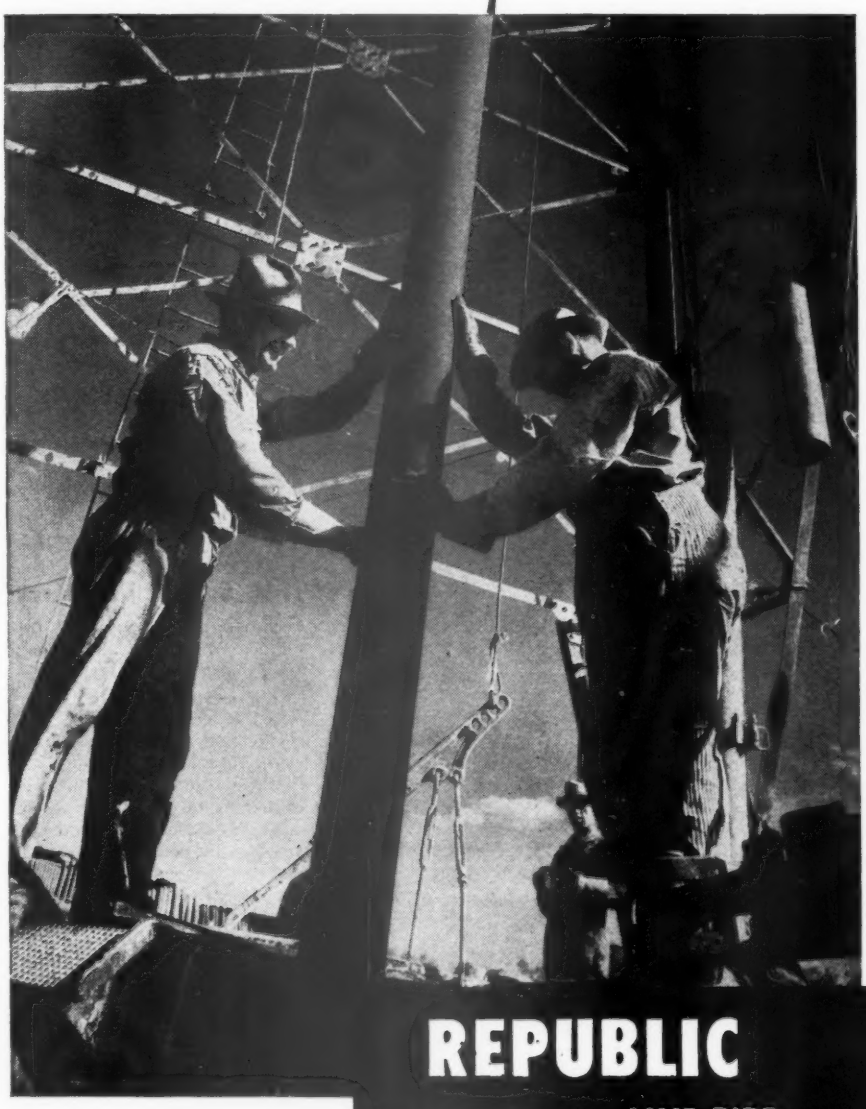
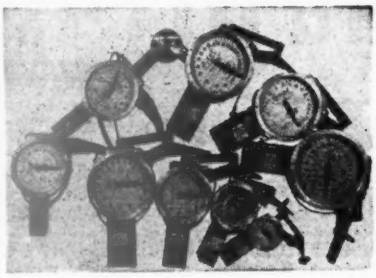


REPUBLIC

LINE PIPE
NORMALIZED CASING AND TUBING

Other Republic Products include Alloy Steels—

LINE SCALES



10 of the 20 Models we manufacture. 40,000 pounds to 500,000 pounds. A special scale for any job.

With a Line Scale you know the pull on the line, and the weight on the bit in pounds. Accurate, sensitive, rugged and economical.

Line Scales are dependable, even in areas of rapid temperature changes. Repeated tests prove the accuracy of Line Scale readings under all working conditions.

See your supply man, now

LINE SCALE CO., INC.

Phone 2-1765, 907-11 SE. 29th Street, Box 4245
OKLAHOMA CITY, OKLAHOMA

YOUR ANSWER TO MATERIAL SHORTAGES

SEE PAGE 2

gives the new hose rope-like flexibility and yet retains maximum ruggedness, Sanborn said.

Designed to stand up under extreme "on-the-job" punishment, the water hose is expected by Sanborn to prove particularly adaptable for construction operations requiring a kinkless, easily-handled conduit. It is built in ¾ in. to 2½ in. sizes.

Also highly flexible, Black Wing air hose is manufactured in two types—two-braid standard for pneumatic tool service, and three-braid heavy duty for air drill usage. Sizes range from ⅜ in. to 1½ in.

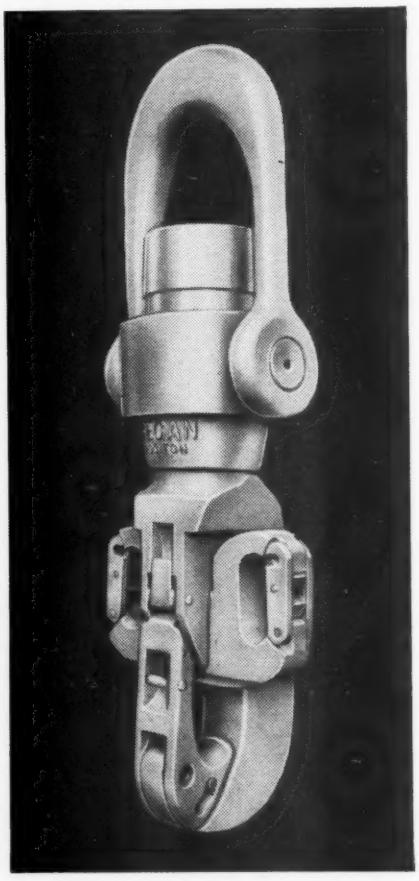
Both products utilize the wartime-developed cabled cotton body for greater carcass strength, and a sturdy, seamless tube unaffected by lubricants that often cause swelling and flaking.

(17) Casing hook

The Regan Forge and Engineering Company is now ready to present to the industry, after more than a year of experimenting and testing in the oil fields, a new all-forged alloy-steel combination casing hook.

This new hook offers some features that never before have been combined in this type of equipment, according to the manufacturer. The following are some of the more outstanding features that this new hook has to offer:

All load-carrying parts of the hook are constructed of forged, heat-treated alloy steel, with more than a 4 to 1 factor of safety. It has been possible to shorten the overall length of the hook to where the height is no higher than most of the connectors that are now being used, for the express purpose of conserving overall height. This has been accomplished by the unique patented design of the yoke sliding down and riding on the hook bight. The type of bail attached to the swivel allows the hook to swing easily because of the flexibility that is possible with this type of construction.



The new type of anti-swiveling mechanism permits approximately 60 deg. reverse rotation when in a locked position, and four locking positions are incorporated.

In the compound spring design, there is a heavy spring for lifting the swivel and kelly and a combination of a heavy and light spring for running drill pipe.

All heavy drilling loads are transferred directly to the swivel block so that excessive shock-loads cannot damage the bearing.

All moving parts are lubricated by positive Alemite lubrication.

The safety features are also worthy of mention: All latches are equipped with automatic locking devices and the main hook latch closes and locks automatically whether the load is picked up on the main hook part or the elevator yoke.

(18) Fire extinguisher

A new mighty midget fire extinguisher has just been announced by America-La-France-Foamite Corporation of Elmira, New York.

It is called the Alfco Speedex—with contents weighing only 3⅝ lb., but which expand upon release to 450 times their contained volume.

It is only $3\frac{5}{16}$ in. in diameter with an overall length of 22 in. It is operated by quick acting squeeze-type valve that releases the carbon dioxide extinguishing agent by palm pressure.

Speedex carbon dioxide gas is non-poisonous, non-corrosive, and odorless. It is a non-conductor of electricity, and will not freeze at any climatic temperature. It is heavier than air and will not support combustion.

The Speedex 3⅝ is an ideal medium for extinguishment of small fires in oils and greases, and in small electrical hazards, the manufacturer asserts. It has its place in the electrical and industrial plant, the office, motorboat, garage, truck, pleasure automobile, and home. Its rating by the Underwriters' Laboratories is B-2; C-2, indicating that two such extinguishers make one unit of first aid fire protection for use on Class "B" fires (flammable liquids, greases, etc.) or Class "C" fires (electrical equipment).

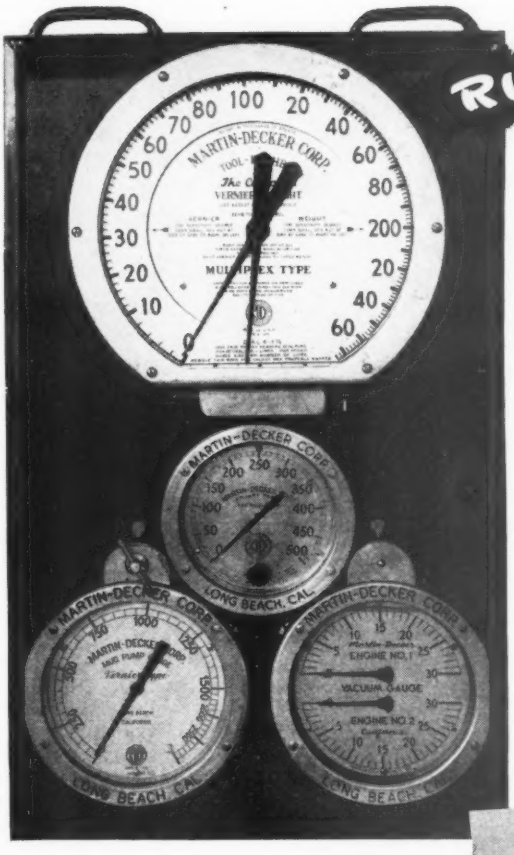
It is shipped fully charged with wall hanger, screws, and rec. rd tag.

(19) Split pillow blocks

The Shafer Bearing Corporation, Chicago, Illinois, announces the "Shafer-Improved" Split Pillow Blocks.

New features of design permit quick and easy installation, removal and replacement of the shaft without misalignment, and with a minimum loss of production time. Positive alignment dowel bolts provide quick, sure alignment of cap, bearing, and base. No separate dowels are needed. The base allows two or four bolt mounting. A big lubricant reservoir, served by a single conveniently located filler hole and a single convenient drain hole, assures better, cooler lubrication, the manufacturer asserts. An outstanding feature is the new Shafer patented Z-type oil seal that positively retains lubrication and seals foreign matter out. The Shafer Improved Split Pillow Block employs the well-known self-contained Series DE-22000 self-aligning bearing, with two roller assemblies, a one-piece outer race, and a spherical inner race. The Shafer Improved Split Pillow Block is universally adaptable to line-shafting or machine installation in all industrial equipment, and is readily interchangeable with all other makes of split pillow blocks.

Combines all the advantages of "Sealtite" construction...



RUGGEDNESS

ACCURACY

Sensitivity

The "SEALTITE" *Clipper*

The Clipper "Sealtite" Weight Indicator and Drilling Control Instrument provides the driller with information on all of the important drilling factors—not just weight alone.

An instrument which reliably shows weight, mud pressure, torque and rotary table speed, and yet is assembled in a small compact case for jackknife derricks, folding masts and derricks, with limited floor space.

It has all the flexibility of a Toolpusher Model but the gauge is not subjected to the violent whip and vibration of the dead line.

You can install or move a Clipper "Sealtite" just as quickly and easily as a Toolpusher type and it will last much longer. Made in a wide variety of combinations... there is a Clipper "Sealtite" available for every purpose.

IT'S TOUGH—The Clipper "Sealtite" is built for rough and ready work and can take it.

IT'S SENSITIVE—Controlled hydraulic operation with a 6 to 1 ratio super sensitive vernier indicates the slightest change in weight on bit or pull on derrick.

IT'S COMPACT and COMPLETE—Weight Indicator and Vernier Indicator, Mud Pressure Indicator, Steam Torque Indicator and Rotary Table Tachometer are mounted and protected in a compact, strong 16" x 16" x 26" steel box. All indicating gauges are available with recorder except the Rotary Table Tachometer.

IT'S MODERN—Immediately adaptable to any type of rig, large or small. The latest thing for use with mast, jackknife, folding derricks or any rig with limited floor space.

IT'S MOVABLE—Just remove weight diaphragm from dead line, unscrew Mud Diaphragm, coil up both hi-pressure hoses, place diaphragm and hoses in box, shut doors and load in car—that's all there is to it.

The Clipper "SEALTITE" is so compact that it is easily transported.

IT'S SEALED—Vacuum loaded at the factory and permanently sealed. No adjusting—no pumping up. The gauge can be set wherever desired for greatest convenience.

The Clipper "Sealtite" is immediately adaptable to any type of rig, large ar small.

Clipper "SEALTITE" installed in small floor space.

HOME OF THE WEIGHT INDICATOR

MARTIN DECKER CORP.

LONG BEACH, CALIFORNIA

SAN JOAQUIN VALLEY T. J. CULLEN, BAKERSFIELD, CALIFORNIA

MID-CONTINENT DISTRIBUTOR REED ROLLER BIT COMPANY, HOUSTON, TEXAS

(20) Blowout preventer

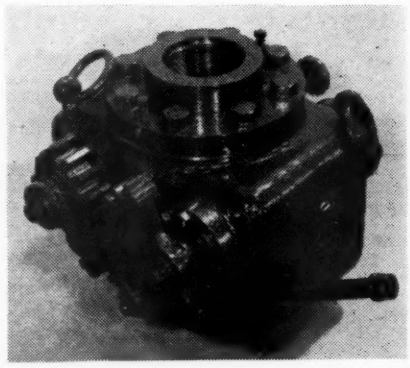
A new, compact, 10,000-lb. test tubing blowout preventer and wire line valve design for higher pressures was recently announced by Oilfield Machine and Supply Company, Houston, Texas.

Design of the new 4-in. preventer incorporates the same quick opening and closing, and pressure seal features of Omsco's 2½-in. wire line valve, it is stated. Pressure is closed off by oil-resistant Hycar rubber rams that seal around the wire line or tubing string. As more pressure is applied against the rams when the valve is closed, the rams seal even tighter. The rams are opened or closed by a 90-deg. turn of the ram arm.

The new light-weight Omsco 10,000-lb. test valve weighs only 430 lb. The valve body is a 16-in. cube—16 in. high, 16 in. wide, and 16 in. deep. Its light weight makes it easily portable.

The 4-in. Omsco valve can be quickly and easily adapted to wire line or tubing service. Rams can be changed simply by removing the top flange and taking out four studs. With "blind" rams it will close off around any size measuring line. With proper size pipe rams, the Omsco tubing blowout preventer will accommodate any size tubing up to 2½ in. external upset. The Omsco valve is provided with either screw or flange connections.

Tests have proved the new tubing blowout preventer and wire line valve to be perfectly adapted to tubing jobs, inside cutting and fishing jobs, and running large tubing calipers on measuring lines, the maker says.

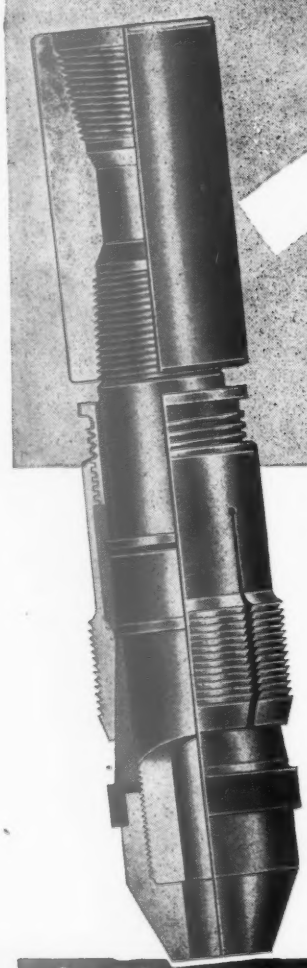


American Releasing & Circulating

SPEAR

has a

QUICK POSITIVE RELEASE



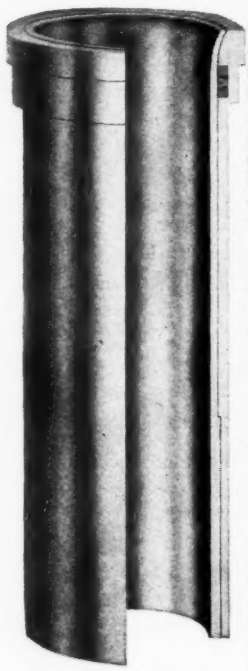
Besides being adaptable to drill pipe, tubing and casing jobs, this "American" releasing and circulating spear can also be used in setting liners, screens and similar production jobs. Each spear can be equipped with special slips for catching many varied sizes. For additional information contact your nearest supply company; your nearest "American" salesman — or write us direct!

AMERICAN
IRON & MACHINE WORKS CO.
OKLAHOMA CITY, OKLAHOMA
Office & Warehouse, Houston, Texas
Export Office: 420 Lexington Ave., New York City, N.Y.

Remember, there is an "American" service man in every active field!

(21) Pump liner

Operators and drilling contractors using slush-type reciprocating mud pumps will be interested to know that Specialty Sales Service of Houston, Texas, has developed a satisfactory and economical method of reclaiming pump liners by the use of a specially designed liner sleeve.



The illustration shows the design of this new liner. At the upper end can be seen the offset provided to hold oil-resistant, rubberized-duck hydraulic packing that protects the liner body against the cutting effect of abrasive mud moving through the pump. It also shows the manner in which the sleeve is rolled on the flange end of the liner.

Any pump liner that has a ⅝-in. wall thickness can be reclaimed to the same size. Any pump liner with ⅜-in. wall thickness can be reclaimed in reduced sizes. Liner sleeves are used for reduced sizes up to and including ¾-in. wall thickness. This provides a range of reduced sizes covering 1½ in. As an example: An 8-in. liner with ⅝-in. wall thickness can be made 8-in. bore or 7¾-in., 7½-in, 7¼-in., 7-in., 6¾-in., or 6½-in.

The liner is manufactured in these steps: (1) Liner body is machined; (2) body is machined from rear to provide offset and offset is machined in flange; (3) liner sleeve is heat-treated and machined to proper measurements; (4) liner sleeve is then pressed into the liner body; (5) liner is then placed in another machine and end of sleeve adjacent to flange end is rolled out, and (6) the complete liner is then finished in a honing machine with a microhoned bore to size.

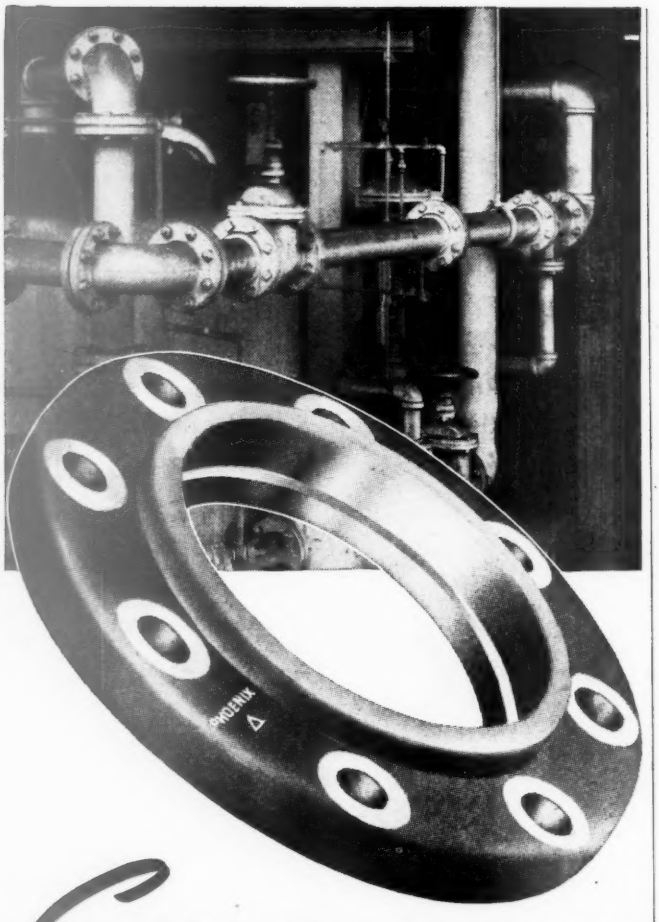
All liners must meet a hardness requirement of 60-65 Rockwell with a tolerance of 3 points before shipment is made. A new liner guarantee is made of this product equal to those on carbonized and flame-treated liners.

WILLIAMS "C" CLAMPS

There's a Williams "C" Clamp for every industrial requirement . . . heavy, medium and light duty, or welding service. All are drop-forged and heat-treated . . . your guarantee of strength, dependability and long life. Williams "C" Clamps are sold by leading Industrial Distributors everywhere.

J. H. WILLIAMS & CO.
BUFFALO 7, N. Y.

WILLIAMS
DROP-FORGINGS AND DROP-FORGED TOOLS



STRONG POINT

in any piping system

That's the Phoenix Flange . . . with all the strength and fatigue resistance that expert forging and machining can impart.

Made of mild steel, especially adapted to welding and machining, Phoenix drop forged flanges comply with ASA requirements and ASME and ASTM specifications.

A complete range of styles and sizes is available to add strong points to your piping system. They are shown in detail in the latest Phoenix catalog.

PHOENIX
Drop △ Forged
FLANGES

PHOENIX MANUFACTURING COMPANY

CATASAUQUA, PA. △ JOLIET, ILLINOIS

TRADE LITERATURE

Publications listed are sent free upon request.

(22) Ex-Cell-O package units

Ex-Cell-O hydraulic power unit bulletin 45361 is a new 16-page booklet that includes engineering information, installation drawings, and application photos of the three sizes of Ex-Cell-O "package units" for feeding and rotating cutting tools. General information is given on the use of these units in building economical special-purpose production machines, as well as specifications and feature details of each unit. Complete particulars are given in the publication on the new Ex-Cell-O Style 20 Hydraulic Power Unit (15¼ in. overall length)—the small compact unit for high spindle speeds and fast cycles.

(23) Ideco steel buildings

The complete line of steel buildings offered by International Derrick and Equipment Company, Columbus, Ohio, is presented in bulletin B-46. Complete details are given by illustrated descriptive material.

(24) FWD five-ton-trucks

The Four Wheel Drive Auto Company, Clintonville, Wisconsin, has recently issued a folder describing its line of five-ton trucks.

(25) ACF valve catalog

The latest valve catalog of the American Car and Foundry Company, New York, New York, has recently been released. This is catalog No. S-46 and its content is concerned with the ACF steel lubricated plug valves. Drawings, photographs, and dimension tables form a considerable part of the text.

(26) Drilling booklets

Patterson-Ballagh Division, Byron Jackson Company, announces the publication of a series of booklets giving information, specifications, installation instructions, parts and price lists of oil field specialties of their manufacture. These booklets are in addition to the 1947 General Catalog, which is now ready for distribution also.

(27) Stonhard resurfacer

A recently published folder describes the use of Stonhard heavy-duty Resurfacer in the repair and resurfacing of floors, traffic aisles, and platforms. It contains a clear, concise description of the properties, advantages, and method of application of Stonhard Resurfacer.

(28) Vapor pressure chart

Phillips Petroleum Company has prepared a large scale vapor pressure chart, entitled "Vapor Pressures of Twelve Four-Carbon-Atom Hydrocarbons." The hydrocarbons included are isobutane, isobutylene, l-butene, 1,3-butadiene, n-butane, trans-2-butene, cis-2-butene, vinylacetylene, ethylacetylene, diacetylene, 1-2 butadiene and dimethylacetylene. Vapor pressures from 0.30 to 800 psia are shown over a temperature range of minus 110 to plus 320°F. The chart, measuring approximately 8 by 24 in. is suitable for mounting on a wall or folded for inserting in a notebook.

(29) Simplex Util-A-Tool

The Simplex Util-A-Tool—"jack of all trades"—pulls, pushes, spreads, bends, clamps, lifts; pulls pinions, bushings, and plain or spoked wheels and gears. "The Tool of a Thousand Uses" is pictured in many operations and completely described in a new bulletin released by Templeton, Kenly Company, Chicago, Illinois, manufacturers of mechanical and hydraulic jacks.

In one unit the Util-A-Tool provides the solution to many problems encountered daily in every type of plant operation. It will straighten frames, push and pull machinery, clamp parts together for welding or assembly, lift and support tractors and other machinery, pull all sizes of wheels, and perform any number of other jobs.

(30) New-matic transmission systems

The Brown Instrument Company, a division of Minneapolis-Honeywell Regulator Company, Philadelphia, Pennsylvania, has issued a new catalog on its New-Matic Remote Transmission Systems for applications where electrical transmission for indicating, recording, and control of temperature, pressure, flow, and liquid level is neither desirable nor permissible.

This new 24-page booklet is profusely illustrated and carries several schematic diagrams of typical applications. Its operating features are fully explained and there is a comprehensive description of the component parts which make up the system. A section of the catalog is devoted to accessories used in the systems, such as control valves, orifice plates, reducing valves, charts, etc.

(31) Uses for Furfural

"Current Uses for Furfural" is the title of the latest bulletin, No. 204, in the series on Furfural and the Furans being published by The Quaker Oats Company, Chemicals Department. This 20-page booklet discusses and illustrates some of the uses of this chemical that have become of active interest to chemists in many different fields of industry.

The uses of Furfural as a selective solvent, a dispersant, resin-former, chemical intermediate, and for other miscellaneous applications are fully covered and give a comprehensive picture of the importance of this chemical to all industry.

(32) Laying pipe lines

The vast network of pipe lines that transports oil and gas from their source to the consumers of the nation involves a series of intricate operations native to no other industry. The story behind such myriad operations themes the booklet "Hills, Bends and Crossings," which has been published by Caterpillar Tractor Company, Peoria, Illinois.

Graphically illustrated, this 12-page color booklet highlights the tasks of pipelaying from initial pioneering to backfilling and includes on-the-spot stories of material wasting, furrowing, stringing and stabbing-in, doping and wrapping, cleaning and priming, welding, and hauling.

(33) Pressure reducing valves

Bulletin 461, 20 pages completely illustrated in color, giving engineering, operating, and maintenance data on pressure reducing valves, differential valves, and overflow valves for steam, air, or gas services, has been issued by Leslie Company, Lyndhurst, New Jersey, manufacturers of regulators, controllers, strainers, and whistles. Large cross-sectional and external views of each class or regulator are shown, together with construction details, exclusive features such as stellited seat rings, and complete tables of pressure ranges, sizes, and capacities.

(34) Kropp stock flange

Kropp Stock Flange List No. 225 has been published by Kropp Forge Company, Chicago, Illinois. This 16-page bulletin illustrates and describes forged steel flanges in boiler, marine, welding, high hub, double hub, tank, spud, offset and horseshoe types; with sectional drawings, complete specifications and list prices. Also included are tables showing American Standards for threads, dimensions of wrought pipe, working and bursting pressures of wrought steel pipe.

(35) Larkin catalog

New price books and 1947 catalogs, featuring the complete line of equipment, were recently distributed by Larkin Packer Company, Inc., St. Louis, Missouri. One of the highlights of the new Larkin catalog is the section devoted to operation and application for Cementrol equipment. The Cementrol principle was developed to supplant conventional methods and to provide a means of overcoming well completion difficulties caused by cement intrusion into the open oil and gas bearing formations below the casing seat.

Postwar design changes in all other Larkin equipment are completely described.

(36) Hewitt hose

Hewitt Rubber of Buffalo, a division of Hewitt-Robins, Inc., currently is distributing a new 6-page printed folder covering the construction and application of rotary drilling and mud pump suction hose. This is produced in three brands: Monarch for heavy-duty deep well work; Ajax for medium depth, and Conservo for slim hole drilling and well work-over.

New product literature covering its general line of industrial hose used in petroleum refining and marketing also is being distributed by Hewitt Rubber. The printed folder describes the construction and application of Monarch brand tank truck, tank car, propane-butane, gasoline pump, and oil suction and discharge hose.

(37) Ohio Injector catalog

Featuring the first postwar general sales meeting of The Ohio Injector Company, Wadsworth, Ohio, manufacturer of steel, iron, and bronze valves, was the introduction of a new 248-page catalog that is expected to become one of the outstanding reference publications of the industrial field.

According to OIC officials, the new catalog sets a new high in the valve industry. It is profusely illustrated with outside and cross-sectional wash drawings of the OIC line and is designed to assist in selecting the right valve for the right job.

ANNOUNCING!

A NEW SYSTEM OF PIPE LINE CATHODIC PROTECTION BY

THE JACOBS WIND ELECTRIC COMPANY

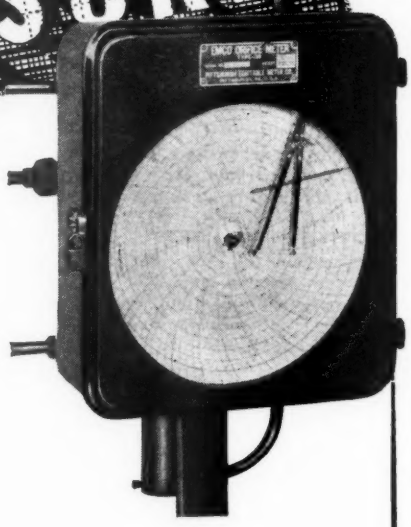
Now you can have practically 100 per cent continuous pipe line protection with the NEW JACOBS SYSTEM at a real saving in current cost. Easy to install, very small annual depreciation and maintenance cost. A new greatly improved and specially designed Wind Electric Plant in combination with a system of current supply during calm periods that maintains almost complete pipe line protection for large or small, coated or bare, oil or gas lines. Lowest annual kilowatt hour cost yet developed for the Cathodic Protection of pipelines.

THE JACOBS WIND ELECTRIC COMPANY

are pioneers in the engineering, development, and manufacture of electric generating equipment for the Cathodic Protection of Pipelines and now offer the pipeline industry an entirely new method of continuous pipeline Cathodic protection at a considerable annual saving in operating, maintenance, and installation costs. It will pay you to get complete details of this new system before considering any other method of Pipeline Cathodic Protection. For complete literature write

THE JACOBS WIND ELECTRIC CO., Inc.
Pipe Line Division
MINNEAPOLIS 11, MINNESOTA

MADE TO MEASURE



THE EMCO GAUGE ALONE

CAN BE *field tailored* TO THE SERVICE

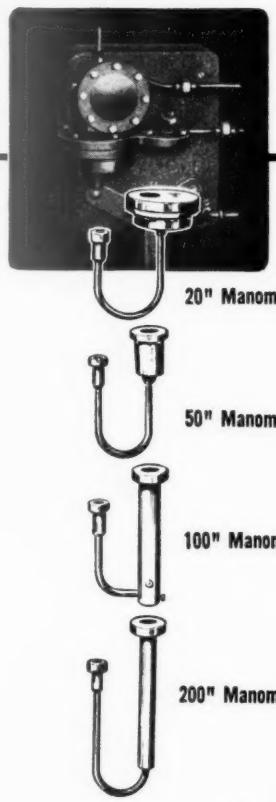
What do you look for in an orifice gauge? Instrument precision? Sound, strong mechanical construction? Service ease and economy? You'll find all these in the Emco design *plus* the added advantage of flexibility—for the Emco Gauge alone may be easily adapted to varying field requirements.

It's done by changing the high pressure chamber, a speedy operation, that, if necessary, can be handled "on location" using only common everyday tools. Learn all about this conversion feature and the other advantages of the Emco Orifice Meter.

Exclusive

HERE'S HOW THE INTERCHANGEABLE CHAMBERS WORK

The EMCO Gauge can be quickly converted to any one of four standard ranges —20", 50", 100" or 200" of water differential by simply changing the high pressure chamber. To do this, it is only necessary to relieve pressure on the meter, drain the mercury, release four flange screws on the high pressure chamber and break the union joint at the bottom of the low pressure chamber.



THE EMCO-McGAUGHY INTEGRATOR

Provides a *precision* method for calculating orifice meter charts of various makes. The machine mechanically computes the total extension which appears on a straight reading register. Accuracy is assured since the operator traces the same recording of static and differential as was made by the orifice gauge. One machine will calculate about 300 average charts per day at a nominal year 'round cost.

ROCKWELL

PITTSBURGH EQUITABLE METER DIVISION

Rockwell Manufacturing Company

Pittsburgh 8, Pa.

instrument accurate

EMCO ORIFICE METERS

THE *Petroleum* Engineer's CONTINOUS TABLES

A DAILY REFERENCE FOR OPERATING MEN

INSTALLMENT No. 114

A VALUABLE and regular feature of *The Petroleum Engineer,* the Continuous Tables, now in their tenth year of publication, were designed to save time and effort for the technician and the practical field or plant worker. The tables have proved one of the most popular and helpful departments of *The Petroleum Engineer.* Data are presented in the simplest form available with many types of information included that are best presented by curves or nomographs when three or more variables must be considered simultaneously.

The Continuous Tables have developed as a result of suggestions for new tables, direct contributions and improvements to existing tables by members of the pertoleum and related industries, including manufacturing concerns, who are continually searching for practical information reduced by computation to tabular form readily applicable to the problems daily confronting them that might otherwise necessitate a more or less tedious calculation. These contributions and suggestions from the industry have resulted in a valuable exchange of information and data contributing to the progress of the industry as a whole.

This index will be revised monthly. The index for installments 1-12, inclusive, will be found in the May, 1938, issue; 13-14, inclusive, in the June, 1939, issue; 25-36, inclusive, in the June, 1940, issue; 37-48, inclusive, in the June, 1941, issue; 48-60, inclusive, in the June, 1942, issue; 61-72, inclusive, in the June, 1943, issue; 73-79, inclusive, in the January, 1944, issue; 80-82, inclusive, in the April, 1944, issue; 83-85, inclusive, in the July, 1944, issue; 86-88, inclusive, in the October, 1944, issue; 89-91, inclusive, in the January, 1945, issue; 92-94, inclusive, in the April, 1945, issue; 95-97, inclusive, in the July, 1945, issue; 98-100, inclusive, in the October, 1945, issue; 101-103, inclusive, in the January, 1946, issue; 104-106, inclusive, in the April, 1946 issue; 107-109, inclusive, in the July, 1946, issue; 110-112, inclusive, in the October, 1946, issue.

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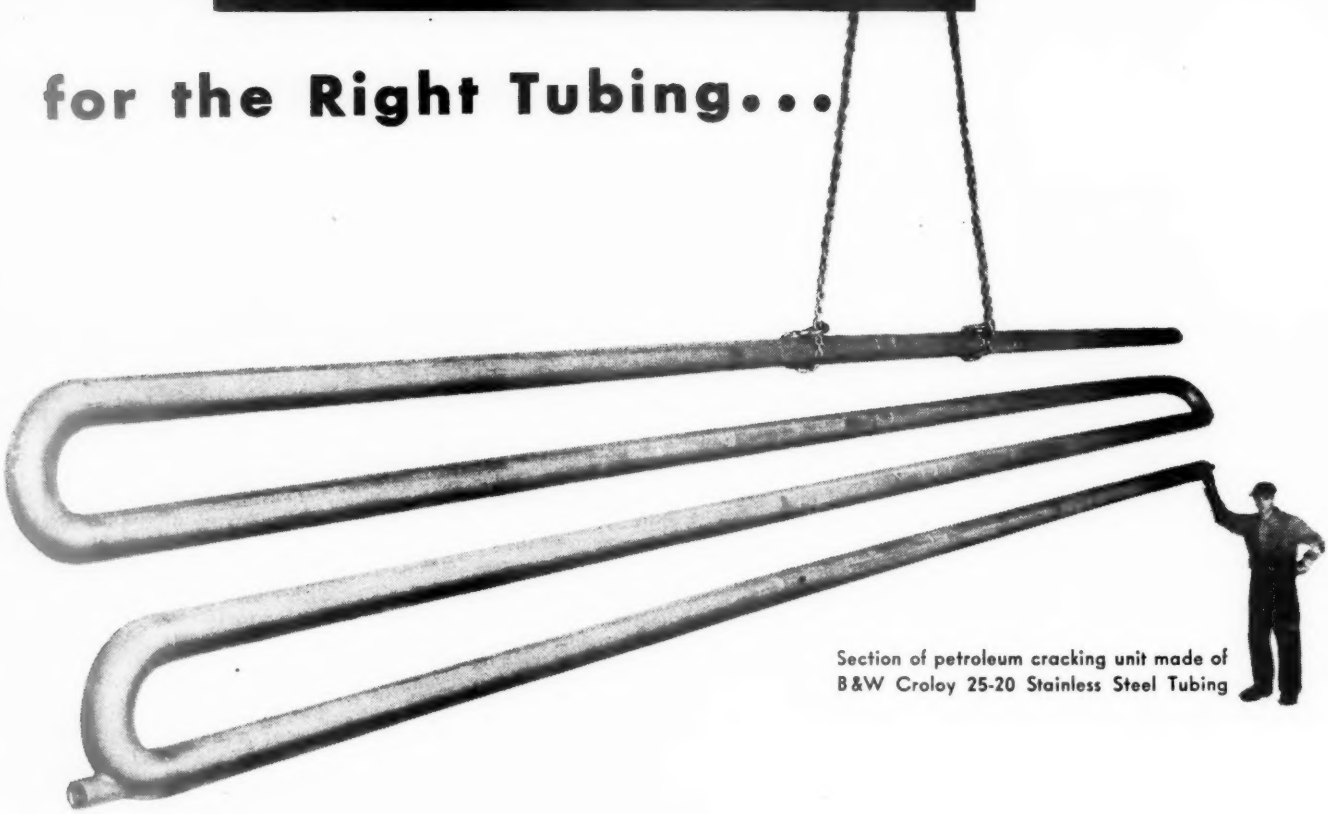

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ANALYSIS OF THE SOURCE OF OIL AND GAS RESERVOIR ENERGY

TABLE 1.
A classification of oil recovery mechanisms.

	1. Dissolved gas drive	2. Gas cap drive	3. Water drive
Other names for these "Drives" or "Controls"	Gas drive Solution gas drive Depletion drive Internal gas drive Dispersed gas drive Capillary control	Segregation drive Gas displacement Gravity drainage Gas cap expansion Volumetric control	Water encroachment Water displacement Water flushing Water flooding Water influx Hydraulic control
Agent supplying or transmitting the energy	Gas	Gas	Water
Usual type of reservoirs	*Closed* to other sources of energy.	*Closed* or *Open*, but not fed by percolating ground water.	*Open* and constantly replenished by percolating ground water.
Usual type of reservoir formation	Porous with capillary-sized flow channels.	Porous, cavernous, or fissured with relatively large flow channels.	Porous, cavernous, or fissured with relatively large flow channels.
Usual porosity and permeability values	Low	Good to high	Good to high
Probable effective drainage area of producing wells	*Limited* by low permeability and Jamin action, or pendular condition.	*Limited* only by energy available in the reservoir to move the oil into the wells.	*Limited* only by the extent of the reservoir feeding the wells.
Figurative definition of each class of recovery mechanism	A reservoir that produces its fluid as from a closed tank full of saturated sandstone of low permeability with its pressure head receding rapidly.	A reservoir that produces as from an open tank of water with its pressure head receding in direct proportion to the volume of fluid produced.	A reservoir that produces as from a water tank that is constantly replenished.
Range of recovery (per cent of original oil in place)	15 to 40	20 to 85	25 to 60
Average recovery (per cent of original oil in place)	20	35	60
Examples	Burkbank, Oklahoma	Mile Six, Peru	Luling, Texas

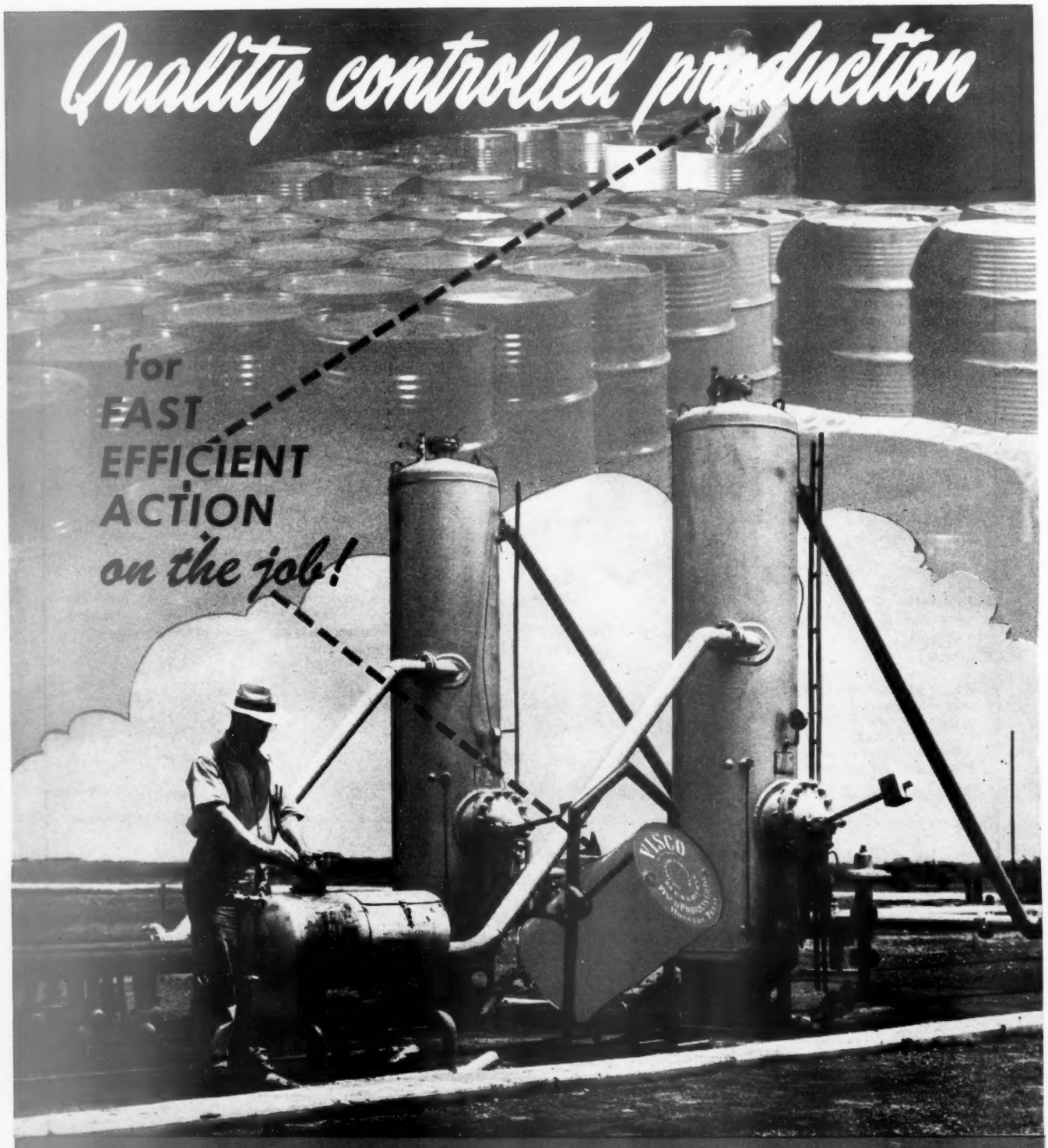
This classification and data are taken from the article entitled, "Oil Reservoir Energy — Analyzing Its Source," by K. Marshall Fagin, in the January, 1946, issue of *The Petroleum Engineer*, pages 218 to 222, inclusive.

Table No. 1 presents a very brief summary of the characteristics of the three principal oil recovery mechanisms. These are sometimes referred to as "drives" or "controls" The various names applied to these three drives are rather confusing to the uninitiated, but this condition exists in part, due to the effort of various people to describe more aptly the degree of effectiveness of a drive, or in some way coin a phrase to fit certain conditions in a particular reservoir that appear to distinguish that drive from another one. Aside from the difficulty of understanding the meaning of the various names of the recovery mechanisms, one must understand the fact that all three may be operating in a reservoir at the same time. This is especially true in water drive reservoirs that produce oil at a high rate.

A small oil reservoir that had an initial reservoir pressure of 2000 lb. per sq. in. might have a water influx (encroachment) rate of 5000 bbl. per day at a reservoir pressure of 1500 lb. per sq. in., and a total production (withdrawal) rate of 10,000 bbl. per day (oil, gas, and water) as calculated at reservoir conditions. In this case, then, the water drive mechanism is responsible for the energy that produces 5000 bbl. being produced by either a gas cap drive mechanism or a dissolved gas drive mechanism or both, and the reservoir pressure may be expected to continue declining until the drop from the initial pressure is sufficient to increase the rate of water influx to 10,000 bbl. per day, or until the total withdrawal rate is reduced to the rate of water influx.

Few, if any, natural resorvoirs may be selected solely on the basis of their production decline curves as being typical examples of reservoirs under dissolved gas drive, gas-cap drive, or water drive. The production decline curve is simply a graphic record of the oil produced by time intervals.

It provides a trend after natural decline begins that is peculiar to the individual reservoir. This trend is helpful in estimating the future oil production, but it does not always indicate conclusively the nature of the energy that causes the production.



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EFFECT OF RESERVOIR TEMPERATURE ON OIL RECOVERY

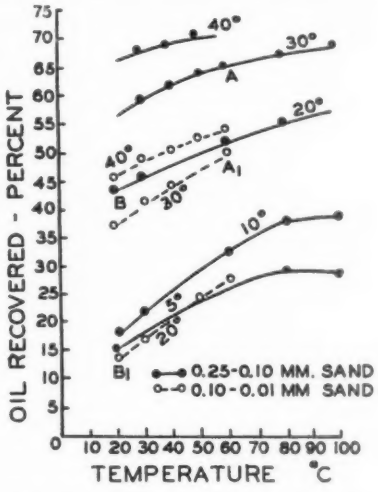

FIG. 2. Changes in the percentage drainage of crude oil from sands of 0.25-0.10 mm. and 0.10-0.01 mm.size as a result of increase of temperature and different slopes of the sand-packed tube.

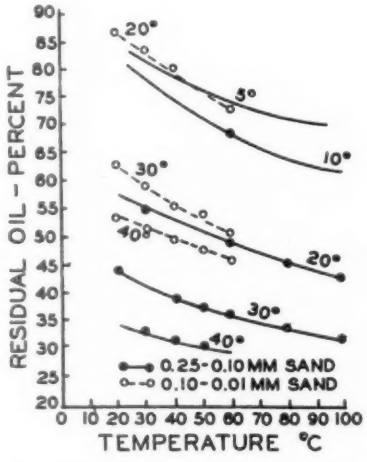

FIG. 3. Residual oil in uncemented sands at different temperatures and different slopes of the tube.

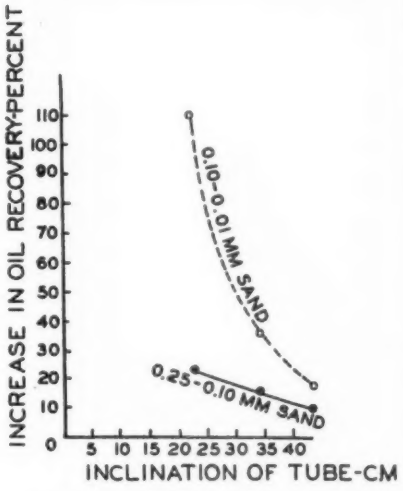

FIG. 4. Increase in the percentage oil recovery due to increase of temperature from 20° C. to 60° C.

These data are taken from the exclusive article entitled "Influence of Temperature on Oil Yield from Uncemented Sands Under Gravitational Flow" by S. L. Zaks as published in the Novembe rissue of *The Petroleum Engineer*, pages 147 to 151.

Fig. 1 (Not shown) is a schematic drawing of the sand-packed tube 2.1 cm. in diameter and 70 cm. long that was used in the experiments that provided the data shown here.

Explanation: The sand-packed tube was saturated with Maikop light crude oil (specific gravity = 0.832, or A.P.I. gravity = 38.57) through a funnel. No oil was left above the sand when the experiment was begun. The tube was placed inside a cylindrical, electrically-heated furnace, and the temperature was maintained constant for each experiment by a regulator. As the oil in the tube was not replenished during the experiment, the head of oil decreased as the oil drained from the sand.

The experiments were carried out in the following manner: The total quantity of crude oil that drained from the sand into a measuring cylinder at the room temperature of 20° C. was determined. After no more oil drained from the sand the temperature in the furnace was increased to 30° C., which caused an additional amount of oil to drain from the sand. The temperature was maintained until no further oil drained from the sand. The total volume of oil recovered was then measured after which the temperature was increased to 40° C., etc.

The experiments were repeated so as to reduce as much as possible the effect of non-uniform packing of the sand grains in the tube.

Table 1 and Fig. 2 show the maximum increase in oil recovered from the sand was observed for increases in the temperature within the range of 20 to 60° C. Fig. 3 shows the percentage change of residual oil in the sand as a function of temperature.

TABLE 1

Size of sand grains, mm.	Position of sand-packed tube		Percentage recovery of original oil at indicated temperature, °C.							Percentage of original oil remaining in the tube at indicated temperature, °C.						
	Slope, degrees	Difference in elevation of ends of sand column, cm.	20	30	40	50	60	80	100	20	30	40	50	60	80	100
0.25-0.10	5	6.0	15.0	18.0			26.0	29.5	30.5	85.0	82.0			74.0	70.5	69.5
0.25-0.10	10	11.7	18.0	21.0			32.0	38.0	39.0	82.0	79.0			68.0	62.0	61.0
0.25-0.10	20	23.3	43.0	46.0			52.0	55.5	58.0	57.0	54.0			48.0	44.5	42.0
0.25-0.10	30	34.0	57.0	60.0	62.0	64.0	65.0	67.0	69.0	43.0	40.0	38.0	36.0	35.0	33.0	31.0
0.25-0.10	40	43.7	66.5	68.5	69.5	70.5	72.0			33.5	31.5	30.5	29.5	28.0		
0.10-0.01	20	23.3	13.5	17.0	19.5	23.5	27.5			86.5	83.0	80.5	76.5	72.5		
0.10-0.01	30	34.0	37.0	41.5	44.5	46.0	50.0			63.0	58.5	55.5	54.0	50.0		
0.10-0.01	40	43.7	46.5	49.0	50.5	52.5	54.5			53.5	51.0	49.5	47.5	45.5		

TABLE 2

Position of sand-packed tube		Size of sand grains, 0.25-0.10 mm.			Size of sand grains, 0.10-0.01 mm.		
Slope, degrees	Difference in elevation of ends of sand column, cm.	Oil recovered at 20° C., cc.	Oil recovered at 60° C., cc.	Increase in oil recovery, per cent	Oil recovered at 20° C., cc.	Oil recovered at 60° C., cc.	Increase in oil recovery, per cent
20	23.3	43.0	52.0	21	13.5	27.5	109
30	34.0	56.5	65.0	15	37.0	50.0	35
40	43.7	66.5	72.0	9	46.5	54.5	17

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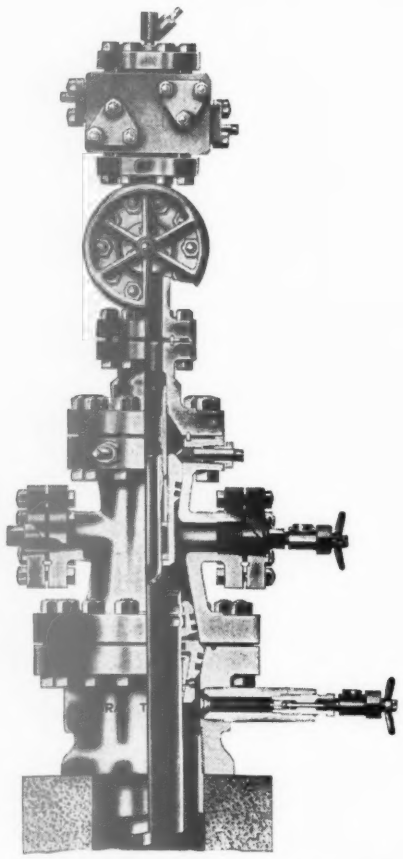

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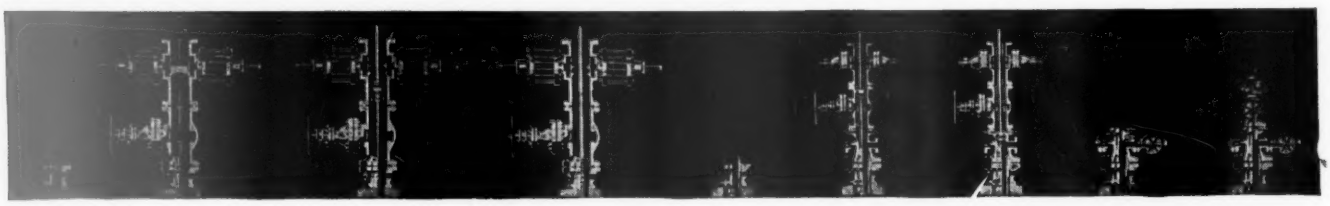

Casing Head Attached | Drilling Well | Running Casing | Casing Landed | Drilling Control Equipment Removed | Drilling-in and Running Tubing | Tubing Landed | Control Equipment Removed | Manifold Attached

CORROSIVENESS OF GAS-CONDENSATE WELL WATERS

These data are taken from the article entitled "The pH of Waters from Gas-Condensate Wells Saturated with Carbon Dioxide at Various Pressures" by H. Arthur Carlson as published in *The Petroleum Engineer* in November, 1946, pages 160 to 164, inclusive.

Table 1 shows the effect of pressure on the pH of water saturated with carbon dioxide at 25°C. (77°F.) as determined by colorimetric measurements in a laboratory. These values agree closely with other determinations which indicate that additional pressure does not decrease the pH of such water much below 3.3 (pH is a measure of the hydrogen-ion concentration).

Table 2 shows the pH of five well waters with salt concentration ranging from 702 p.p.m. to 141,623 p.p.m., saturated with carbon dioxide at pressures of 20, 40, 60, and 80 lb. per sq. in. The pH is related to the partial pressure of the carbon dioxide present and not to the total pressure.

Table 3 shows the calculated partial pressure of carbon dioxide and an estimated pH at the wellhead assuming equilibruim, together with production information on the 5 wells.

Table 4 shows the chemical analyses of the 5 well waters. The total solids may vary considerably with the rate of production, depending upon the amount of condensation of water. The two water samples taken from Well B on different days is an example of this variation. Oftentimes the variation is greater than in this particular case.

Table 5 shows that the pH of sodium chloride solutions saturated with carbon dioxide varies directly with increasing concentrations of the salt. This is to be expected inasmuch as increasing the salt concentration will decrease the solubility of the carbon dioxide.

TABLE 1

pH of carbon dioxide solutions at 25° C. (77°F.) colorimetric measurements.

CO_2 pressure in lb. per sq. in. abs.	pH
20	3.8
40	3.6
60	3.5
80	3.4

TABLE 2. pH of carbon dioxide saturated well waters.

Well	Date sampled	Total solids in p.p.m.	Initial pH of water	pH at indicated CO_2 pressure, lb. per sq. in.			
				20 lb.	40 lb.	60 lb.	80 lb.
A	2-23-45	702	6.45	4.6	4.4	4.3	4.2
B	4-10-46	7,653	5.4	4.6	4.4	4.3	4.2
B	8-18-44	15,858	4.6	4.5	4.4	4.3	4.1
C	5- 1-46	37,498	8.0	5.5	5.2	5.2	5.2
D	3-14-46	141,623	6.3	4.7	4.6	4.5	4.4

(a) Atmospheric pressure (no carbon dioxide added)

TABLE 3. Production data.

Well	A	B	B	C	D
Date sampled	2-21-45	4-10-46	8-18-44	3-25-45	3-14-46
Formation	Sand	Lime	Lime	Sand	Brown Dolomite
Reservoir temperature, °F.	230	218	218	210	Estimated 85
Reservoir pressure, lb. per sq. in.	5200 calc.	4900 calc.	6300 calc.	3895 at 8950 ft.	..
Wellhead flowing temperature, °F., est.	170	140	140	170	85
Wellhead flowing pressure, lb. per sq. in.	3300	4100	4554	2700	..
Production rate, million cu. ft. per day	6.68	1.45	....	2.1	..
Distillate production, bbl. per day	211	138	....	80	1
Water production, bbl. per day	10	2	....	4	225
CO_2 in gas, mole per cent	0.96	1.88	1.88	0.99	..
Calculated partial pressure, CO_2, lb. per sq. in.	32	77	85	27	..
Estimated pH at equilibrium	4.5	4.2	4.1	5.4	..

TABLE 4. Water analyses—(p.p.m.)

Well radical (p.p.m.)	A	B	B	C	D
Total solids	702	7,653	15,858	37,498	141,623
Sodium and potassium	195	1,877	4,111	13,843	50,867
Silica	....	....	....	....	....
Iron	52	141	Present	None	....
Calcium	19	924	1,705	441	2,543
Magnesium	8	74	158	101	1,056
Chlorides	187	4,688	9,692	21,459	83,060
Bicarbonates	239	74	90	1,636	247
Sulphates	4	16	102	24	3,850
Hydrogen sulphide	Absent	Absent	Absent	Absent	Absent
Organic acids	159	Present	Present	Present	..
Gravity at 60°F./60°F.	0.9960	1.0067	1.0142	1.0244	1.1057
pH	6.45	5.4	4.6	8.0	6.3
Date sampled	2-23-45	4-10-46	8-18-44	5-1-46	3-14-46

TABLE 5

The pH of sodium chloride solutions saturated with CO_2.

Concentration parts per million	20 lb. per sq. in.	40 lb. per sq. in.	60 lb. per sq. in.	80 lb. per sq. in.
100,000	4.3	4.1	3.9	3.7
10,000	4.2	3.9	3.8	3.7
1,000	4.1	3.8	3.7	3.6
100	3.9	3.7	3.6	3.4
0	3.8	3.6	3.5	3.4

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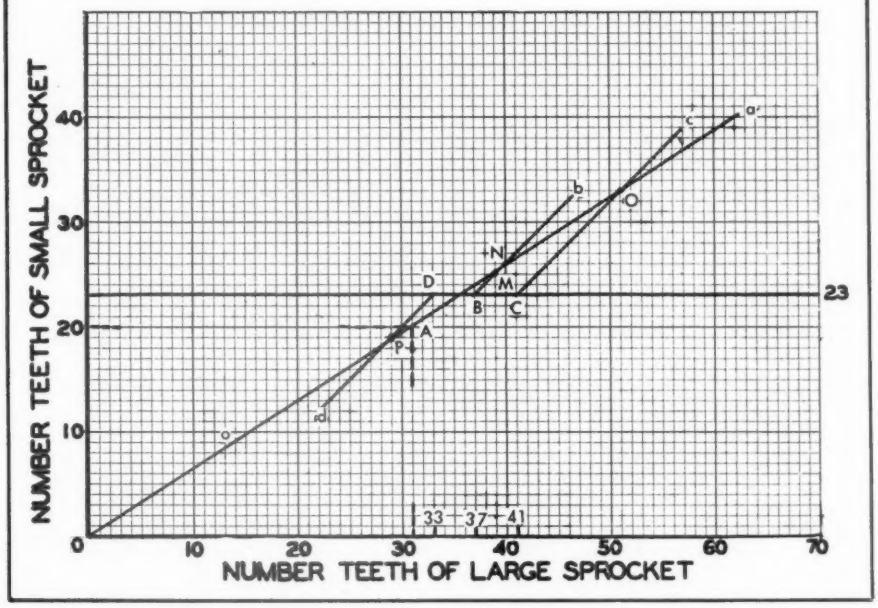
GRAPHIC METHOD OF SELECTING ROLLER CHAIN DRIVES

FIG. 1. Diagram showing number of teeth of the large sprockets marked on the abscissa and the number of teeth of the small sprockets marked on the ordinate.



This method of selecting roller chains for multiple speed transmissions is taken from the exclusive article on the subject by Walter Brown that was published in the November issue of *The Petroleum Engineer*, pages 156 to 158. The exact formula for the centerdistance of chain drives reads:

$$C = \frac{L - \frac{N}{2} - \frac{n}{2} + \sqrt{\left(L - \frac{N}{2} - \frac{n}{2}\right)^2 - 8\left(\frac{N-n}{2\pi}\right)^2}}{4}$$

Where: C = centerdistance in pitches
L = chain length in pitches
N = number of teeth of large sprocket
n = number of teeth of small sprocket.

In a system of rectangular coordinates such as Fig. 1, a straight line at an inclination of 45° (such as B-b) represents all chain drives having the same centerdistance.

Example of graphic method:

We have a chain drive consisting of a 23 and a 62-tooth sprocket and a chain 88 pitches long. The centerdistance is 21.865 pitches. We want to design a second drive with the same shaft centers having a sprocket ratio of about 20:31.

A line, "o-a," drawn from the zero point through point A ($x = 31$, $y = 20$) represents all points corresponding to the desired sprocket ratio 20:31. A horizontal line "23" ($y = 23$) represents all drives having a small sprocket of 23 teeth.

In a centerdistance table, covering the combination of a 23-tooth sprocket with a complete line of large sprockets, one or more drives are selected with centerdistances differing from the centerdistance of the first drive (21.865) less than one-tenth of a pitch. The corresponding points are marked on the horizontal line for the 23-tooth small sprocket. The points C, B, and D, for instance, have the following characteristics:

Point	Number of teeth of large sprocket	Chain length in pitches	Centerdistance in pitches, "C"	Difference between "C" and 21.865
C	41	76	21.812	— .053
B	37	74	21.8865	+ .0215
D	33	72	21.943	+ .078

The intersections between line "o-a" and lines "B-b," "C-c," and "D-d" (drawn at an angle of 45° from the points B, C and D) give the desired solution. Line "B-b," for example, intersects with line "o-a" near point M corresponding to a sprocket ratio of 25 to 39. The corresponding chain length would be 76 pitches (74 plus 25 minus 23). Another possible solution would be point N corresponding to sprocket ratio of 26:40 and a chain length of 77 pitches. An odd number of pitches in the chain requires an offset link.

Line "D-d" originating from point D located to the left of the intersection between line "o-a" and the 23-tooth line gives point P, corresponding to a drive of 19 and 29 teeth and a chain length of 68 links (72 — 23 + 19).

In a similar way line "C-c" produces at point "O" a solution with 33 and 51 teeth and 86 pitches of chain.

Which one of these solutions should be used or whether still other solutions should be investigated will depend on considerations such as shaft diameters safety factor, limiting speeds or space requirement.

The described method eliminates the work of having to solve a complicated formula containing two second powers and one square root. It will give the designer more time to investigate the speed pattern of his rig, enabling him to select a more favorable one, and solve his problems more rapidly than heretofore.

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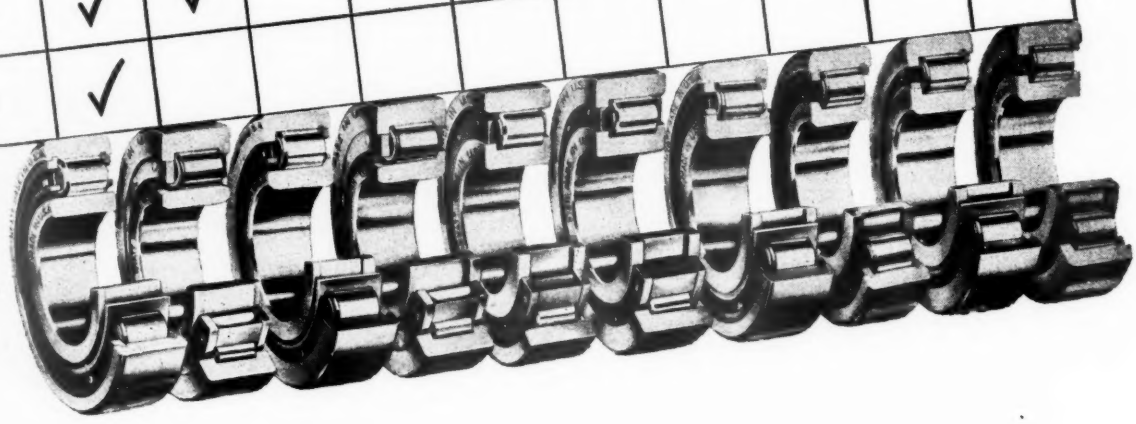
1200	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
1300	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5000		✓			✓					
5200	✓	✓			✓		✓	✓		
5300	✓	✓			✓		✓	✓		
6200	✓									



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ECONOMICAL ALIGNMENTS FOR PIPE LINES*

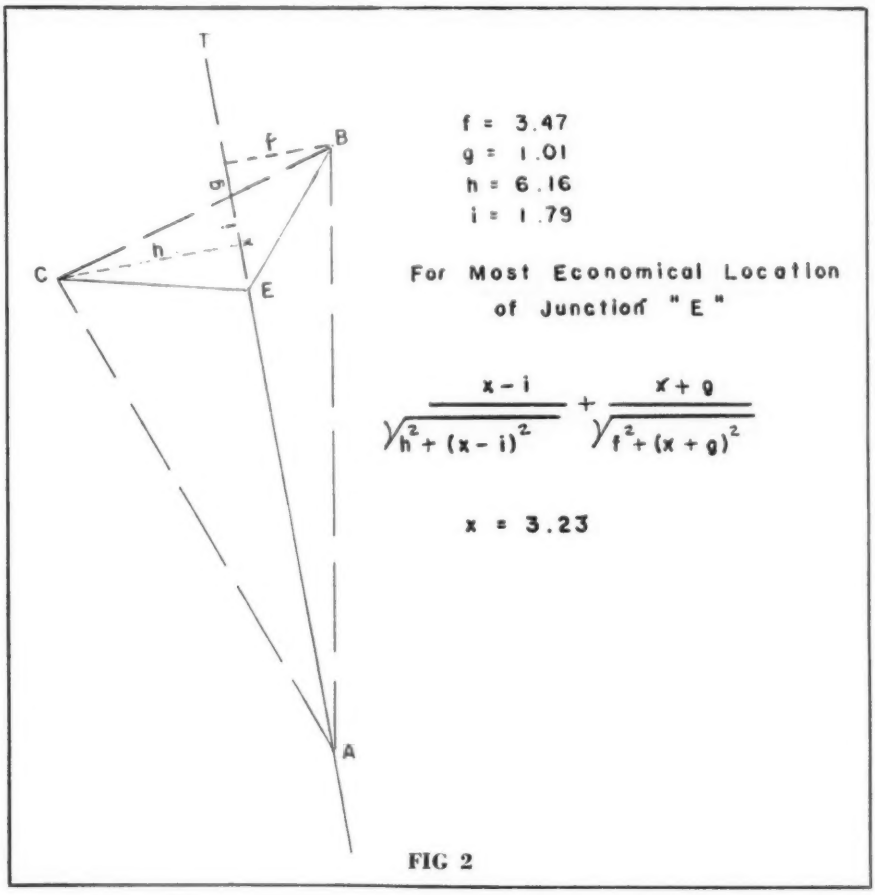


FIG 2

*This chart and formulas are taken from an article with the above title by Peyton Bryan, Assistant Division Engineer, Humble Pipe Line Company, that was published in the October, 1946, issue of *The Petroleum Engineer*, p. 212.

(3) A third case will often arise, in which the branches "B - E" and "C - E" can be of the same diameter, with a larger pipe required for their common outlet, "E - A." Letting M represent the unit cost of the "B - E" and "C - E" branches, and N the unit cost of the "E - A" line:

$$x = \frac{\sqrt{(a^2+x^2)(b^2+x^2)}}{\sqrt{(a^2+x^2+N/M\sqrt{b^2+x^2}}} \quad \text{equation (3)}$$

Example: (Refer to Fig. 1, Sheet 1).

Assuming 4 in. for the two branches, and 6 in. for 'E - A" in the second triangle of Fig. 1, at the same estimated unit costs as before:

$$x = \frac{\sqrt{(225+x^2)(25+x^2)}}{\sqrt{225+x^2}+8.0/4.8\sqrt{25+x^2}}$$

The value of x is found to be 3.73, giving 6.27 miles of 4 in. from "C" to "E," 6.23 miles of 4 in. from "B" to "E," and 15.45 miles of 6 in. from "E" to "A." The use of equation (3) saves $4400 compared with the usual perpendicular connection.

(4) It will sometimes be necessary to extend the pipe line toward "B" and "C" upon some given and arbitrary tangent, say the line "A - T" of Fig. 2, which for some reason (perhaps in order to parallel a railroad or highway) must be followed. It is desired to find the most economical point for the junction. By the same process as for the derivation of equation (1), it is found that this location "E" is given by:

$$\frac{x-i}{\sqrt{h^2+(x-i)^2}} + \frac{x+g}{\sqrt{f^2+(x+g)^2}} = 1$$

. . . . . equation (4)

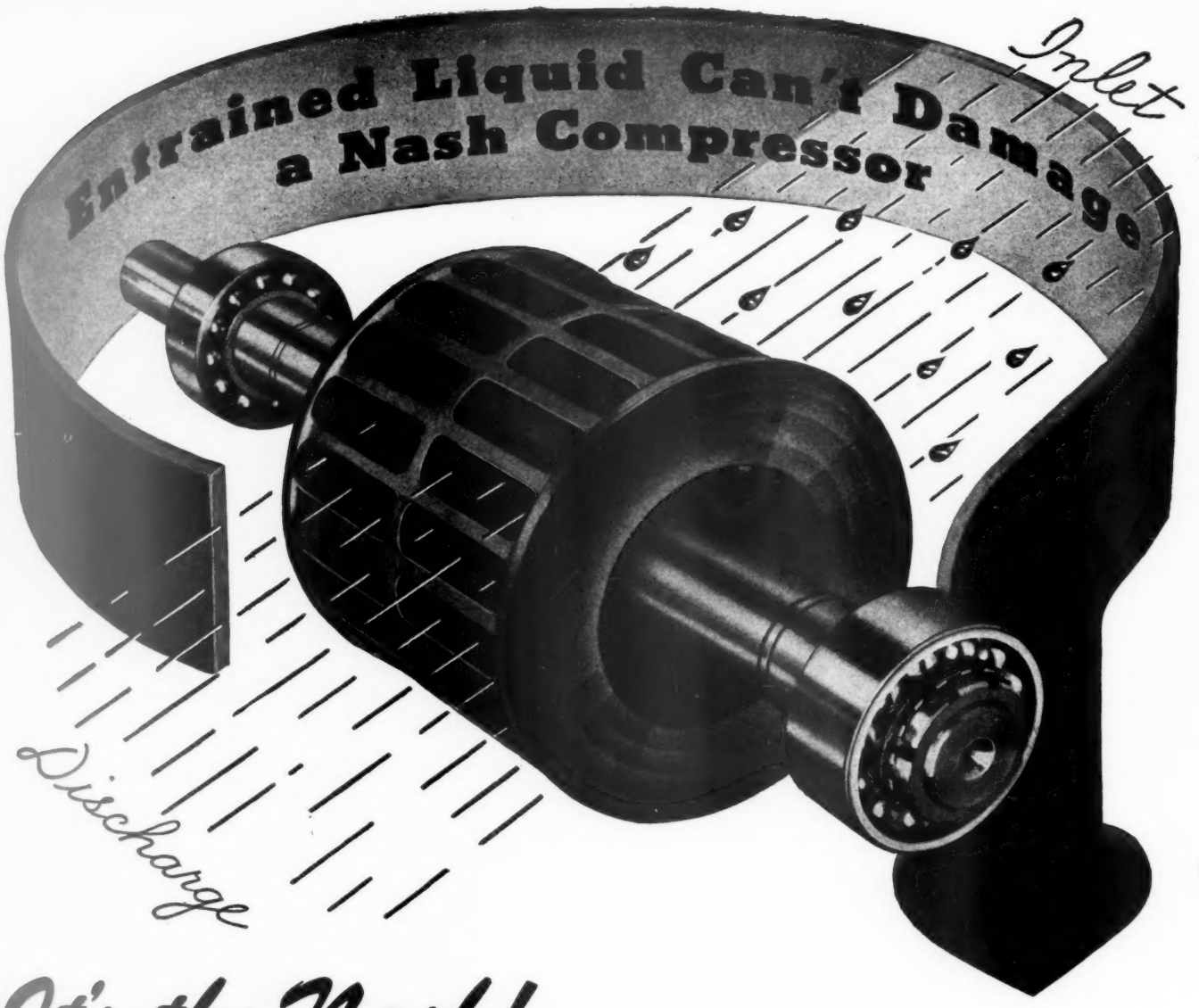
In using this equation, the required tangent is produced beyond the points to be connected, and the perpendicular distances f and h are scaled or calculated. A line "C - B" is drawn between the two points and the distances i and g from this line to the feet of the perpendiculars are also scaled or calculated. With these four distances, equation (4) is solved by trial for the most economical location of the junction "E." It will be noted that in this equation the behavior of the function with respect to x is contrary to that of the previous equations, i.e., the relative value of the function increases with an increase in the value of x.

(5) If the diameter of the branches "C - E" and "B - E" is different from that of the line "E - A," equation (4) is changed to:

$$\frac{M}{N} = \frac{x-i}{\sqrt{h^2+(x-i)^2}} + \frac{x+g}{\sqrt{f^2+(x+g)^2}}$$

. . . . . equation (5)

wherein M represents the unit cost of the line "E - A," and N represents the unit cost of the branches "C - E" and "B - E."



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The ability of Nash Compressors to maintain original performance thruout a long life is only one of the many advantages which derive from the Nash liquid piston principle of compression.

Since this liquid piston is an integral part of the Nash Compressor, additional liquid can do no harm to the pump structure, whether in the form of slugs entering by accident, or as condensate forming in the suction lines. In handling gases, for example, wet hydrocarbons, usual elaborate protective devices are eliminated. The hazards of such devices are therefore avoided, the cost of installation is saved, and freedom from repairs and shutdowns is assured.

Nash Compressors produce 75 lbs. pressure, or vacuums to 26 in. of mercury, in a single stage. with capacities to 6 million cubic feet per day in a single structure. They have but one internal moving part, simple and non-wearing. There are no valves, gears, pistons, sliding vanes, or other enemies of long life. No gas contaminating internal lubricant is employed. Compression is without pulsation. It will be to your advantage to investigate the Nash Compressor.

26 in. mercury vacuum or 75 lbs. pressure in one stage.

No internal wearing parts.

No internal lubrication to contaminate gas handled.

Desired delivery temperature automatically maintained.

Non-pulsating pressure.

Original performance corstant over a long pump life.

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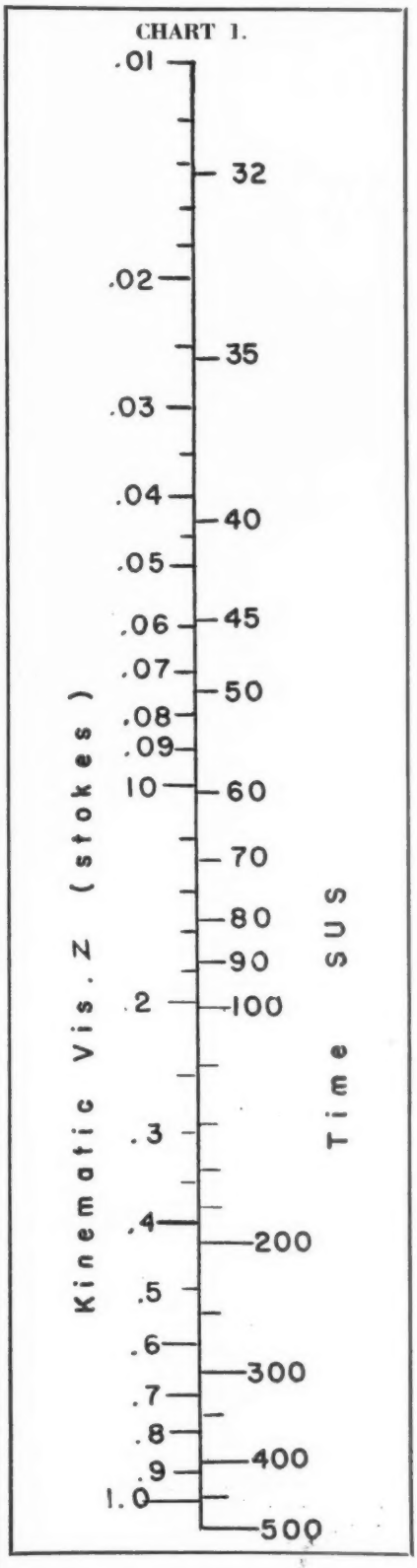
METHODS OF COMPUTING FLOW OF OIL IN PIPE LINES

CHART 1.



These data are taken from the article entitled, "Simplified pipe line computations," by Peyton Bryan, in the November, 1946, issue of *The Petroleum Engineer*, pages 166 to 168, inclusive.

TABLE 1
Friction factors (from W. F. Durand)

Reynolds number (R) in thousands	Friction factor (f)
5	0.0382
6	0.0364
7	0.0350
8	0.0340
9	0.0330
10	0.0320
12	0.0304
14	0.0292
16	0.0280
18	0.0271
20	0.0264
25	0.0249
30	0.0238
35	0.0228
40	0.0219
45	0.0213
50	0.0208
60	0.0200
70	0.0195
80	0.0190
90	0.0185
100	0.0180
150	0.0168
200	0.0158
250	0.0150
300	0.0144
350	0.0140
400	0.0137
450	0.0184

$$R = 22.14 \frac{B}{d\,z}$$

$$h = f \frac{15.25\ B^2}{d^5}$$

$$p = f \frac{34.95\ s\ B^2}{d^5}$$

Most pipe-line flow equations may be expressed in the form:

$$H = f \frac{L\,V^2}{2\,g\,D}$$

Wherein:

H is the height, in ft., of the column of liquid required to impart a velocity of V ft. per sec. to 1 lb. of the liquid, through a pipe of length L ft. and diameter D ft. The units chosen for L and D may be any you like, but they must be the same for each term, which is a disadvantage, for pipe diameters are usually expressed in inches whereas pipe-line lengths are expressed in feet or miles.

The rate of flow (V) may be expressed as bbl. per hr. (B), and taking the value of g, the acceleration of gravity, at 32.16, we can rewrite the equation so as to express D in inches and L in feet:

$$H = f \frac{(12)\,(L)}{(64.32)\,(d)\,(12.233\,d^4)}\ B^2$$

$$= f \frac{0.01525\ L\ B^2}{d^5}$$

It will also be convenient to have H represent a definite gradient, or rate of fall in "head," just as B represents a definite rate of flow. Considering L equal to 1000 ft. in the above equation:

$$h = f \frac{15.25\ B^2}{d^5} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and h is the hydraulic gradient, or loss of head per 1000 ft., occasioned by the flow of B through a pipe of diameter d inches. More properly, B is the flow occasioned by the hydraulic gradient h.

As most pressure gauges are calibrated to read in pounds per square inch, we should have an equation to fit them. Referring to the first form of equation (1), the pressure, in pounds per square inch, exerted by a column of liquid of height H is:

$$P = \frac{62.5\ s\ H}{144} = 0.434\ s\ H$$

$$H = \frac{P}{0.434\ s}$$

with s meaning specific gravity. As with equation (1), the pressure equation is more covenient in the form of a definite gradient; in this case, the pressure drop in pounds per square inch, per mile. Considering L equal to 5280 ft., and expressing H in terms of P:

$$p = f \frac{(0.434\ s)\,(0.01525)\,(5280)\ B^2}{d^5}$$

$$= f \frac{34.95\ B^2\ s}{d} \quad . \quad . \quad . \quad . \quad . \quad (2\text{-a})$$

The customary oil industry expression for gravity being in deg. API, which unit is converted to specific gravity by the equation

$$s = \frac{141.5}{(API + 131.5)}$$

we can substitute this value in equation (2-a), and get

$$p = f \frac{4945\ B^2}{(API + 131.5)\ d^5} \quad . \quad . \quad (2\text{-b})$$

With f being a function of a dimensionless quantity called the Reynolds Number written: $R = \frac{D\,V}{z}$

with R as the Reynolds Number, D as pipe diameter in feet, V as velocity of flow in ft. per sec., and z as kinematic viscosity, which is usually expressed in a unit of the metric system called the stoke. As before, we want to express pipe diameter in inches, and velocity in terms of B, so the final Reynolds equation will be:

$$R = 929.03 \frac{d}{12}\ z\ \frac{B}{3.5d} = 22.14 \frac{B}{d\,z}$$

Unfortunately, there is no practical means of measuring directly the kinematic viscosity of a liquid, but its value can be obtained from the indications of viscosimeters. The time, in seconds, required for 60 cc. of the sample to flow through the tube of the Saybolt Universal Viscosimeter is the most widely used expression for viscosity among pipe-line engineers. (Chart 1.)

Example: It is required to find the pressure necessary to pump 275 bbl. per hr. through 10 miles of 4-in. line, the oil having an API of 42 deg. and viscosity of 35 SUS.

From the conversion chart, 35 SUS is equivalent to a kinematic viscosity of 0.026 stokes.

$$R = 22.14 \frac{275}{4(0.026)} = 58{,}540$$

$f = 0.0201$

By equation (2-b)

$$p = (0.0201) \frac{(4945)\,(275)^2}{(42 + 131.5)\,(4)^5} =$$

42.3 lb. per sq. in per mile

or 423 lb. per sq. in pressure required for the 10 miles.

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REFRIGERATION AND HORSEPOWER CALCULATIONS

THIS chart and data are taken from the articles on "Refrigeration and Horsepower" by W. F. Schaphorst as published in the January, 1946, issue of *The Petroleum Engineer*, page 222, and the November, 1946, issue, page 202.

The chart is based on theoretical values as found in most engineering handbooks and may be used for determining refrigeration and horsepower equivalents on at B.t.u. basis as explained.

There is no practical direct relationship between compressor horsepower and tons of refrigeration, however, for much of the work of refrigeration in cooling and freezing processes is done by the cooling water, or air, or other cooling mediums. The amount of refrigeration that may be accomplished by a given compressor horsepower varies with the refrigerant, the pressure-temperature conditions of the refrigerant expansion, the efficiency of the heat exchange between the refrigerant and the cooling water, air, or other medium, and many other factors. The horsepower that drives the compressors may, therefore, do only a small portion of the theoretical work required to obtain the total amount of refrigeration required. On a B.t.u. versus hp. basis many refrigeration plants operate at more than 400 per cent efficiency.

For instance, the conventional ammonia or propane refrigeration plant operates on the following cycle: Compression, condensation, expansion, and evaporation of the refrigerant. The only mechanical horsepower requirements are during the compression part of the cycle. The amount of horsepower so required may easily be determined by the use of a Mollier chart on the refrigerant being used, or determining the enthalpy of the gas at suction conditions and the enthalpy at discharge pressure under constant entropy conditions. Thus, it may be seen that the actual horsepower requirements will vary according to the pressure-temperature conditions, but in any event will not approach the total heat of refrigeration due to the large extraction of heat in the condensation of the refrigerant material.

CHART

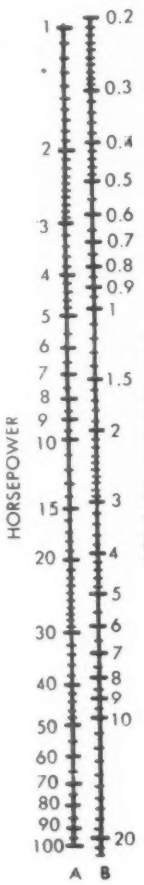


Chart is based on theoretical values. A ton of ice represents 288,000 B.t.u. And since one B.t.u. is equal to 778 ft.-lb., and there are 33,000 ft.-lb. in a horsepower per minute, it is evident that the theoretical relationship can be readily determined. The chart shows that one horsepower is equivalent to 0.21 ton of refrigeration, or, 10 horsepower is equivalent to 2.1 tons. In other words, with an overall refrigerating machine efficiency of 100 per cent a 10-hp. motor would produce 2.1 tons of ice in 24 hr. A 100-hp. motor would produce 21 tons of ice in 24 hr.

For example if you should want to know the theoretical equivalent of 6 tons of refrigeration, you use the chart in this way: Find the 6 in column B and glance across to column A. The answer is 29 hp.

Illustration: Using propane as refrigerant:

Suction conditions,
5°F., 42 lb. abs. = 279 B.t.u. per pound
Discharge conditions, (constant entropy)
155 lb. abs. = 305.5 B.t.u. per pound
Work of compression = 26.5 B.t.u. per pound
Saturated vapor,
5°F., 42 lb. abs. = 279 B.t.u. per pound
Saturated liquid,
86°F., 155 lb. abs. = 157.6 B.t.u. per pound

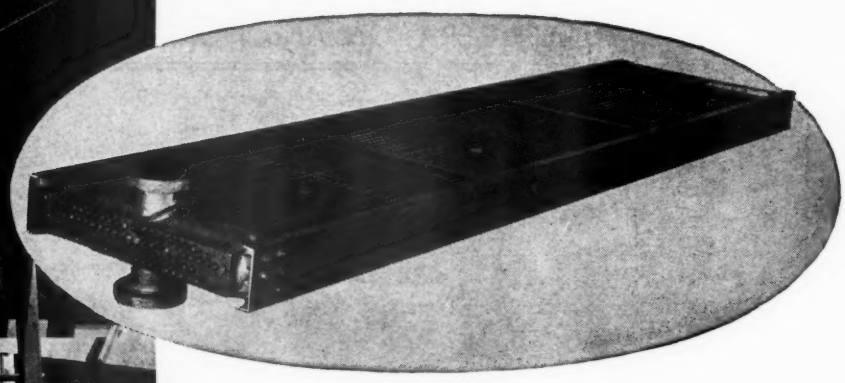
Net refrigeration available 121.4 B.t.u. per pound
One ton of refrigeration = 200 B.t.u. per min.

$$200 \text{ B.t.u. per min} \left(\frac{200}{121.4}\right) = 1.647 \text{ lb.}$$

*Horsepower per ton is $\frac{26.5 \times 1.647 \times 60}{2545} = 1.03$

*This value will vary with actual conditions of operation

Refrigeration processes depend so much on the temperature of the cooling water, cooling air, or other cooling mediums that nearly all refrigeration processes situated in temperate climates will provide considerably more refrigeration capacity than the theoretical amounts shown in the chart above, but the chart is useful for basic comparisons, inasmuch as it takes either the theoretical amount of horsepower to make a ton of refrigeration or an equivalent amount of cooling by the cooling water, cooling air, or other refrigerant condensing medium.



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Running Tour WITH MEN IN THE INDUSTRY

• **Charles A. Perlitz, Jr.,** well known Houston oil man and attorney, was elected executive vice president of Continental Oil Company at a board meeting in New York City, it was announced by President Dan Moran at Ponca City. Perlitz succeeds **W. W. Bruce,** who retired November 1 under Continental's retirement annuity plan. Born March 3, 1903, at Schulenberg, Texas, Charles Perlitz is one of the youngest senior executives of a major oil company in the United States. He moved as a boy to Houston, where his father is president of The Schuhmacher Company, a wholesale grocery firm, and where the younger Perlitz graduated from high school. He received his A.B. degree from Georgetown University, Washington, D. C., in 1925, and his LLB. degree from Harvard in 1929.

C. A. Perlitz, Jr.

From 1929 to 1938 he was a member of the law firm of Fulbright, Crooker and Freeman, Houston, and for the next seven years was associated with Strake Petroleum, Inc., Houston, a large independent producing company. He joined Continental Oil Company as general attorney at Houstor on January 1, 1946.

• **R. A. Feemster** has been employed by the American Iron and Machine Works Company as special sales representative out of the Oklahoma City office. Feemster, prior to his present position, served as division sales manager for Kobe, Incorporated for approximately five years. He is a graduate of the University of Oklahoma Petroleum Engineering School and was employed for several years by Phillips Petroleum Company and later by Baroid Sales Company.

• **J. A. Clark,** vice president of the Creole Petroleum Corporation, has resigned to accept a position as an executive assistant in the office of the coordinator of foreign and domestic production of the Standard Oil Company (N. J.). The resignation became effective December 1. Clark has been with Jersey Standard and its affiliated companies for more than 23 years, most of this time being spent with Creole in Venezuela.

R. H. Sherman, a vice president and director, assumes the duties formerly assigned to Clark as coordinator of operations of the Creole Petroleum Corporation in the New York office. Sherman recently arrived from Venezuela where he spent the last 13 years directing Creole's geological activities. He has been associated with the Creole Petroleum Corporation and other affiliated companies of the Standard Oil Company (N.J.) for more than 18 years.

• **A. L. Nickerson** has been elected a member of the board of directors of the Socony-Vacuum Oil Company, Inc. A native of Dedham, Massachusetts, Nickerson was graduated from Harvard. He went to work for Socony-Vacuum in August, 1933, as a service station salesman and rose through various positions in the company's marketing operations to the assistant managership of the eastern marketing division. In 1945, he went to London as chairman of the board of the Vacuum Oil Company, Ltd.

• **H. H. Glen,** president of the Emsco Derrick and Equipment Company, announces the following organization staff changes:

C. L. Lamkin, vice president, has been moved from the Houston plant, where he served as plant manager, to the main Emsco offices at Los Angeles. In his new position, Lamkin will concern himself with all phases of the company's business from the standpoint of management.

C. L. Lamkin

H. H. Glen

Paul Courtney

J. T. Tucker

Paul Courtney, formerly sales manager of the Houston branch, has been appointed manager of the Houston plant to succeed Lamkin. His position as Houston sales manager has been filled by **J. T. Tucker,** who previously served as field service manager for the Emsco Derrick and Equipment Company in the Mid-Continent area.

• **Carl W. Meyers,** president of the Colorado Fuel and Iron Corporation, announces the election of **A. F. Franz** of Pueblo, Colorado, as vice president in charge of operations. He will succeed **Robert T. Dunlap** of Buffalo, New York, who has resigned. Franz is a native of Cleveland, Ohio. Before joining the Wickwire Spencer Steel Division of the corporation at Buffalo, as general superintendent of the Buffalo plant, he was associated with the Allan Wood Steel Company of Conshohocken, Pennsylvania. Franz was appointed works manager of the Colorado division last March. In his new position he will have complete charge of all operations of the corporation.

• **Harry W. Huber,** a sales and field service representative of Spang and Company of Butler, Pennsylvania, was killed in a plant accident on November 18, his birthday. He was 48 years old and had worked for the Spang company for five years. Since the war Huber had been occupied at the plant more than in field work. He was caught between the cab of a crane and the mechanism of a heat-treating furnace and was crushed to death. Born in Clarion County, Huber lived in Brookville and was engaged in drilling and gas production when he joined Spang and moved to Butler in 1941. He is survived by his widow, five sons, and one daughter.

• **Frank E. Bergeron** has been named manager of Baash-Ross Tool Company's export department in New York City. Bergeron has been with the Baash-Ross organization for many years and brings to his new post not only a thorough working knowledge of the wide range of advanced drilling, production, and fishing tools that Baash-Ross manufactures, but also an unusually well-rounded background of oil field experience. After graduating from the school of geology at the University of California at Los Angeles, Bergeron spent a number of years as a mining engineer and geologist in major fields throughout the West. After joining the Baash-Ross organization some 11 years ago, he advanced through various manufacturing and sales posts to the position of sales manager where he gained valuable experience handling much of the company's export affairs in addition to his regular duties as sales manager. It is from that position that he has been moved to his new duties as export manager. Concurrent with the appointment of Bergeron as export manager, the Baash-Ross Tool Company has enlarged its export offices, which are now at 11 West 42nd Street, New York 18, New York.

F. E. Bergeron

• **Howard Hansen** has been named supervisor of the office of **J. L. Singleton,** manager of district offices of the Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin. Hansen, who attended the University of Wisconsin, joined Allis-Chalmers in 1941. Since that time he has worked in the company's works accounting department, blower and compressor department, and in the administrative office of **William C. Johnson,** vice president, general machinery division.

P. W. Foster, Jr.

• **Pell W. Foster, Jr.,** vice president and director of the Foster Wheeler Corporation, has been appointed vice president in charge of production. He has been associated with the company for 27 years, was elected a vice president in 1942 and a member of the board of directors in 1938.

• **Dr. Edwin E. Whitehead,** recognized power authority, has been appointed secretary of the Midwest Power Conference, Stanton E. Winston, director, announces. Whitehead, who was recently appointed research professor in Illinois Institute of Technology's engineering department, will succeed **Charles A. Nash,** I. I. T. professor, who has had seven years tenure in office. Dr. Whitehead has been associated with the Duquesne Light company for the last 14 years as research supervisor, operating engineer, investigating engineer, and general engineer. An alumnus of the University of Colorado and the University of Pittsburgh, he is well-known for his work in lightning studies and system studies.

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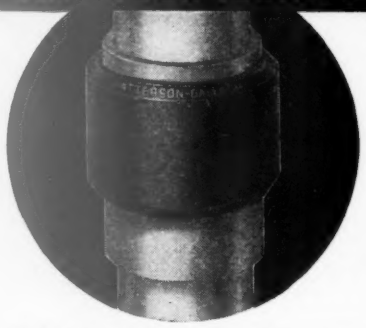

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FOR OIL COMPANY AND PROCESS INDUSTRY EXECUTIVES

SEE PAGE 2

• **Ivan C. Alspach** has returned to Akron as manager of mechanical goods for Goodyear Tire and Rubber Export Company. Since 1944 he has been the company's mechanical goods representative for the Atlantic seaboard, with headquarters in New York. Succeeding Alspach in New York is **William H. Klippert,** a member of the company's mechanical goods sales staff since 1944.

Ivan C. Alspach

A native of Delaware, Ohio, Alspach joined Goodyear in Akron as a tire builder in 1927. Later he was transferred to the accounting division, and in 1934 was made sales manager of Goodyear's subsidiary, the Wheeling Township Coal Company, Adena, Ohio. He joined Goodyear Export Company in 1944. Alspach attended the University of Akron after finishing high school in Lakewood, Ohio.

• **Charles R. Allen,** formerly proration engineer for Continental Oil Company, Ponca City, Oklahoma, has been appointed California region manager of the company's production department, with headquarters in Los Angeles, it is announced by President Dan Moran.

This appointment follows the retirement of **R. E. Collom,** vice president, who has been in charge of Continental's California production operations for the last 15 years,

C. R. Allen

R. E. Collom

and who retired December 1 under the company's annuity plan. Collom will continue, however, to serve as the company's director of the important Kettleman North Dome Association.

A native Californian, Charley Allen has been on Continental Oil Company's production staff for more than 23 years. Born at Oakland, he attended school there and served as an army captain during World War I. After a few years with another oil company he joined Continental in 1923. Since then he has served the production department in supervisory positions at Tulsa, Oklahoma; Edmonton, Alberta, Canada; Fort Collins, Colorado; Hobbs, New Mexico; Evansville, Indiana, and on March 1, 1946, was named proration engineer.

Roy Collom is well known to the oil fraternity throughout the United States, having served the industry for more than 30 years.

• **J. E. McFate,** formerly manager of tubular sales at Houston, Texas, for Republic Supply Company, recently opened an office at 7440 Midland Avenue, Detroit, Michigan. He will handle accounts of several tubular fabricators, including The Sawhill Manufacturing Company, Sharon, Pennsylania. He is covering Michigan and Toledo, Ohio.

• **Norman J. McGaw,** general vice president, New York, moves to the Shell Oil Company's San Francisco headquarters in a similar position. McGaw is a former San

N. J. McGaw

H. S. M. Burns

Franciscan, having joined Shell in 1925 as a statistician in the San Francisco office. He became assistant to the president in St. Louis in 1933 and has been a vice president of the company since 1939.

A second appointment elevates **H. S. M. Burns,** widely known in the industry and a former resident of the bay region, to the senior vice presidency of Shell's east of the Rockies territory. He will make his headquarters in New York. Burns joined Shell more than 21 years ago in California as a geophysicist in the exploration department.

• **Reginald L. (Tony) Middleton,** veteran in selling and engineering fields, has joined the sales force of the Falk Corporation, Milwaukee, as sales representative in the Dallas territory. He makes his headquarters in his Dallas office, 3304 Lovers Lane. For 12 years he has been associated with the Continental Supply Company, first as district manager of machinery sales in Tulsa, then as director of purchases in the Dallas office until he resigned early this year.

R. L. Middleton

Previously Middleton was an oil field specialist in the sales division of General Electric Company in Tulsa, the position he took after his graduation from Mississippi State University where he received a bachelor of science degree in electrical engineering.

• **Joe R. Carnes, Jr.,** Houston, Texas, joined the sales organization of Clayton Mark and Company, manufacturers of Petro, Hydro, Mark, and Handle-Bar forged steel unions, to represent the company in the Mid-Continent oil fields.

J. R. Carnes, Jr.

Carnes was recently discharged from the Army Air Forces with the rank of captain attached to the European Theatre where he was a bomber pilot on a B-17, as well as a courier pilot of a P-38 and flew unarmed over enemy territory.

It has taken Joe five years to realize his ambition to enter the sales profession because the Army got him immediately after he finished school.

Carnes will make his headquarters at 1752 West Main Street, Houston 6, Texas.

• **R. E. Post,** veteran representative of Fairbanks, Morse and Company, who has for the last decade been manager of the firm's Washington, D. C., office passed away in a Washington hospital recently. Bob, as he was well known by his host of friends in army, navy, and civilian circles, had a long and illustrious career with the E. and T. Fairbanks and Company. Beginning with the scale organization he joined Fairbanks, Morse and Company when the two organizations were merged. He joined the latter company in 1923 and was for many years manager of their Baltimore branch. Later he became manager of the Washington, D. C., office, which position he filed until his death.

• **L. H. Billings** has been appointed district manager of a newly created Falk Corporation sales territory, it was announced recently by Walter L. Schneider, vice president and director of sales. Formerly production manager at Falk, Billings directs sales in Wisconsin, Upper Michigan, and parts of Iowa. After joining the company as a co-op student 20 years ago, Billings worked in the engineering and estimating departments for several years. He then entered the advertising department, where he later became advertising manager. His next step was to the order department as manager. In 1941 he was named production manager.

B. C. Bugbee

L. H. Billings

Shortly following Billings' promotion, came the announcement from Harold F. Falk, works manager, that **B. C. Bugbee** had been named production control manager. Associated with the company for the last five years, Bugbee was a member of the plant engineering department until 1944 when he became assistant to the works manager, the position he held at the time of his promotion.

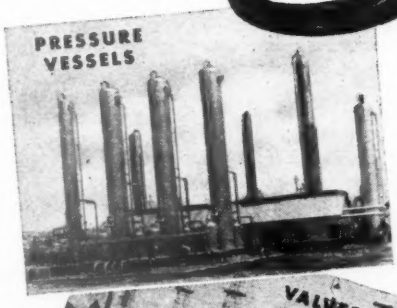
• **Chester F. Smith,** a director of Standard Oil Company (N. J.), and for more than 35 years associated with the company in manufacturing and engineering operations, has been named a vice president, it was announced by **Eugene Holman,** company president.

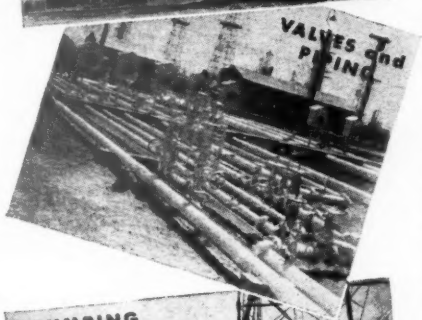
Since 1944, Smith has been a chairman of Jersey's Coordination Committee, a central study and advisory group for the managements of companies in the Jersey group. Members of the committee are appointed by the board and include executives of some affiliated companies as well as department heads of the parent company.

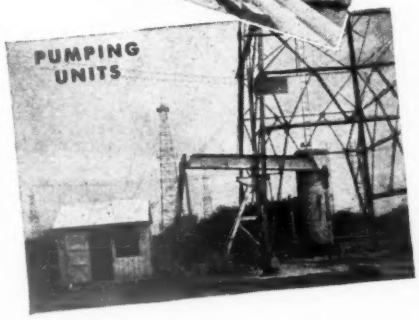
• **H. D. "Curley" Grothusen,** engineer and member of the board of directors, Gas Advisers, Inc., 60 Wall Tower, New York, New York, has resigned to join the Stanolind Oil and Gas Company, Tulsa, Oklahoma, as assistant superintendent of the gas and products sales section, manufacturing department. Grothusen graduated from Kansas State Agricultural College in 1927 with a bachelor of science degree in civil engineering. He is a member of the technical section of the American Gas Association, and a licensed professional engineer in New York.

LESS TROUBLE AVOIDING TROUBLE

for field and refinery equipment inspection, rely upon the portable *MAGNAFLUX unit







• Fatigue cracks, casting defects, unsound welds—these are the flaws common to field and refinery equipment . . . flaws that often cause early equipment failure. You can conveniently and economically eliminate these costly failures with the new, portable Magnaflux unit.

Because it unerringly ferrets out these flaws . . . quickly outlines their size, shape and location with easily read indications . . . inspection with Magnaflux is the ideal defense against faulty equipment risks. Because it is portable and self-contained . . . permits easy, on-the-spot inspection . . . this new Magnaflux unit is the ideal answer for use in the oil industry.

The new KRH-2 Magnaflux unit, pictured above with the XB-2A Powder Blower, gives low-voltage, high-amperage outputs—both AC and half-wave rectified current, for either AC or DC magnetization and demagnetization after inspection. This unit is most suitable for both surface and sub-surface defect location.

Write today for complete data and free copy of the latest Magnaflux bulletin.

MAGNAFLUX CORPORATION

*MAGNAFLUX—Registered U. S. Patent Office, a trademark of the Magnaflux Corporation applied to its equipment and materials for magnetic particle inspection.

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Wall Cleaning Guides

(Patented and Patents Pending)

Both Safe and Effective in Cementing the Deepest Wells

Sometimes we get the question: What about B & W Wall Cleaning Guides in deep wells, where high temperatures make thick mud cake, all conditions are more severe, and the job of cementing is more difficult?

Well, a look at the record is the best way to show that B & W Guides are just as effective in deep wells as in shallow. Here are just a few of our many successful deep well jobs:

DEPTH	NO. OF GUIDES	SIZE CASING
13150′	12	4¾″
11744′	46	5½″
10875′	30	7″
10500′	33	7″
10419′	33	7″
10000′	48	5½″
10000′	15	5½″
9800′	40	5½″
9700′	106	5″

No matter what the depth, B & W Wall Cleaning Guides on the casing—plus casing movement while cementing—center the casing, remove mud cake and distribute the slurry around the casing for a successful cement job *the first time,* reducing the need for costly and dangerous recementing. Our new Bulletin 104 tells all about it. Why not send for it, now, while you think of it?

BRUCE BARKIS — B and W INCORPORATED — KENNETH WRIGHT

Well Completion Specialists

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Long Beach, Calif. • Phone: L. B. 4-8366
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Houston, Texas • Phone: Preston 9783

LAUGH WITH BARNEY

Izzy rushed up to his friend, very excitedly, "Oh, Abie, I hear you are going to marry Reba," he said. "Don't do it. She's been out with every guy in Peoria."

"Well," queried Abie, "is Peoria such a big city?"

* * *

"Yes," said the specialist, as he stood at the bedside of the sick purchasing agent, "I can cure you."

"What will it cost?" asked the sick man faintly.

"Five hundred dollars."

"You'll have to shade your price a little," replied the purchasing agent. "I had a better bid from the undertaker."

* * *

Then there was the sailor who treated all his girls to wine. He wanted a little port in every sweetheart.

* * *

Cop: No parking. You can't loaf here.
Voice from car: Who's loafing?

* * *

What the average woman wants is a strong, inflexible man who can be wrapped around her finger.

* * *

Boss: Come into my office right away, Joe. Something's up!
Assistant: Ha! A big deal?
Boss: No, a little blonde's shade in a hotel room across the street.

* * *

As the caller tipped his hat to the woman standing on the porch, she said: "If you are looking for my husband, he's gone fishnig. Just walk down to the bridge and look around until you find a pole with a worm on each end."

* * *

YA CAN'T WIN! When your wife's toe sticks out of her shoe, she's fashionable. When yours does, you're a bum.

* * *

Housewife: And are you really content to spend your life walking about the country, begging?
Hobo: No, lady, not at all. Many's the time I wished I had a car.

* * *

Teacher: How many bones have you in your body?
Willie: About a thousand.
Teacher: That's a good many more than I have.
Willie: Well, I had sardines for lunch.

* * *

Do you love your enemies?
Yes, all three of them: Tobacco, Women and Liquor.

* * *

We know a Scotchman who for two cents will throw a penny away.

* * *

"That's a good-looking hat you're wearing."

"Yes, I bought it five years ago, had it cleaned three times, changed it twice in restaurants, and it's still as good as new."

* * *

Romeo: Since I've met you I can't eat, drink, play or sleep.
Lorelei: Why not?
Romeo: I'm broke!

* * *

The girl who slaps you may not want to hurt your feelings so much as she wants to stop them.

Santa Claus to the Little Boy: And did you get any bad marks in school today?
Little Boy: Yes, Santa, but they're not where they'll show.

* * *

"How dare you swear before my wife?" demanded the indignant husband.

"I am very sorry," replied the little man celebrating Christmas, "I was unaware that your wife wanted to swear first."

* * *

We're getting terribly tired of driving a car that's paid for.

* * *

A conference is a gathering of important people, who singly can do nothing, but collectively decide that nothing can be done.

* * *

A hill billy had been calling on his girl for almost a year, when Pappy decided to corner him and see just how the situation stood. "Tell me now, Zeb, you've been a-calling on my Nell for nigh on a year. What are your intentions, honorable or dishonorable?"

The hill billy's eyes sparkled as he replied, "You mean I gotta choice?"

* * *

A British sailor and an American sailor were bragging about the merits of their respective navies. Said the British sailor: "Why, our ships are so big that our captain has to ride around the deck in his automobile." To which the American sailor replied: "That's nothing. The galley is so large on our ship that the cook has to cruise around in the stew in a submarine to see if the vegetables are done."

* * *

Junior: Daddy, what's a sweater girl?
Daddy: A girl who works in a factory making sweaters. (A slight pause.) Say, where'd you get that question?
Junior: Never mind that, Daddy; where'd you get that answer?

* * *

Pastor: Good morning, May. I hear God has seen fit to send you two little twin brothers.
Little May: Yes, sir, and He knows where the money's coming from, too. Daddy said so.

* * *

Jose (who likes to brag): Juan, I theenk I weel sheep 50 bools to the bool fight in Mexico City.
Juan (who sees all, hears all and says little) doesn't bother to reply.
Jose: Juan, I theenk I weel sheep 100 bools to the bool fight in Mexico City.
Juan still remains silent.
Jose (striking the bench with his fist in desperation): Juan, I theenk I weel sheep 150 bools to the bool fight in Mexico City. What do you theenk of that?
Juan: I theenk you are a beeg bool sheeper.

* * *

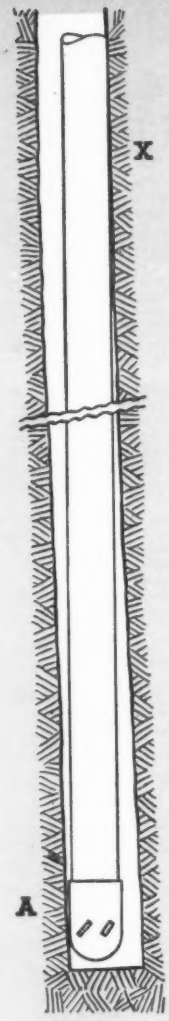
Gert says that a necking party is an affair which invariably lasts until someone gives in, gives up or gives out.

* * *

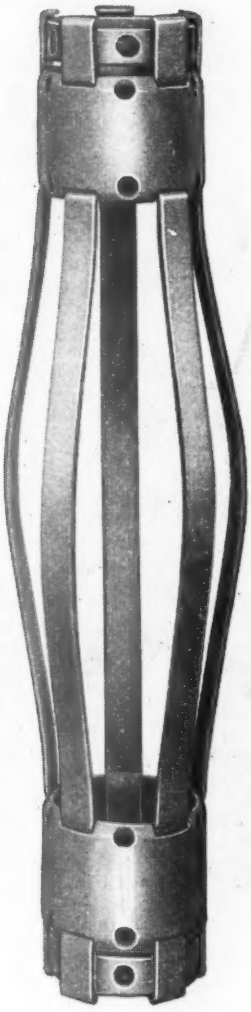
It's hard to date women workers. They aren't satisfied with a good time—they want time and a half!

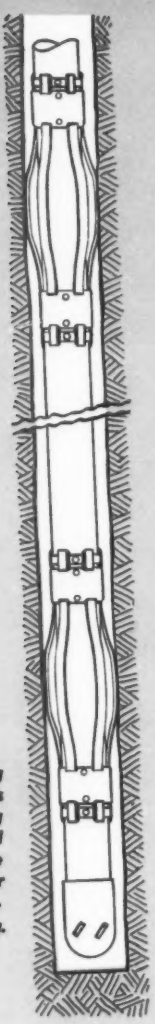
* * *

"Hello, Jones. I understand you people employ a trouble shooter. Could I borrow him? I've got a little trouble I'd like to have shot."



Casing hanging vertically in a hole that is slightly off vertical contacts the hole at points "A" and "X". This is a frequent cause of cementing failure.





Use of Baker Casing Centralizers insures centering of casing in the hole at all critical points—the ideal condition for successful "first-time" cementing.

IT PAYS TO CENTER CASING

When casing is off-center and leaning against the side of the hole at the shoe joint (left view above) the hazard of channeling is obvious. It is also easy to see why so many cementing jobs are failures because it is impossible to place a uniform body of cement ALL AROUND the casing at the vital shoe joint when the casing is not centered. So long as this condition exists, there are sure to be failures to secure good water shut-offs as well as other cementing failures.

Now let's study the drawing at right which illustrates how Baker Casing Centralizers (Product No. 910) provide a uniform annulus for placement of cement entirely around the casing at critical cementing points, and minimize the danger of channeling. Baker Casing Centralizers are simple and effective; they are easy to install and use; they are inexpensive and can be secured promptly through your nearest Baker office or representative.

BAKER OIL TOOLS

It's Time to Center YOUR Casing!

If you would like a copy of the New BAKER Casing Centralizer Broadcast, which describes and illustrates many important applications, address Baker Oil Tools, Inc., Box 127, Vernon Station, Los Angeles 11, California.

BAKER OIL TOOLS, INC., LOS ANGELES • HOUSTON • NEW YORK

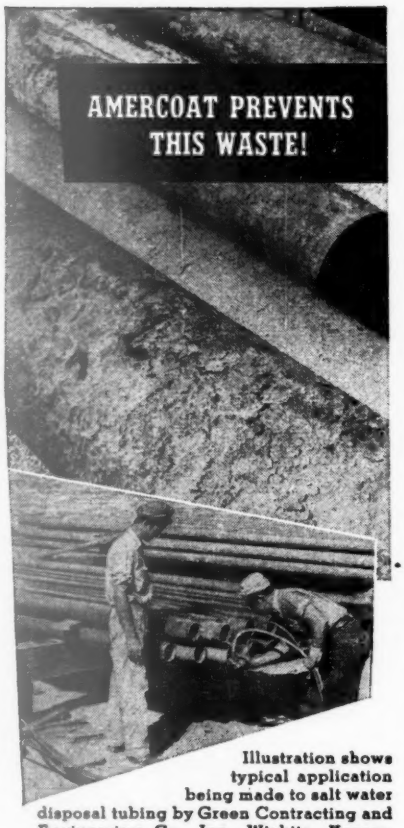


Illustration shows typical application being made to salt water disposal tubing by Green Contracting and Engineering Co., Inc., Wichita, Kansas.

GET POSITIVE PROTECTION WITH AMERCOAT

Ravages of corrosion send millions of dollars worth of pipe and other costly equipment to the junk pile before its time. AMERCOAT produces a long-lasting, non-brittle coating that gives positive corrosion protection. In addition, there is negligible reduction of inside diameters and much lower friction loss.

Since AMERCOAT is unaffected by salt water, crude, acids, alkalies and sulfur compounds, it is being successfully used for the protection of:

Production Tubing • *Injection Well Tubing* • *Chokes* • *Disposal Tubing Packers* • *High Pressure Gate Valves Submerged Pumps and Motors* • *Sour Crude Tanks* • *Line Pipe*

Cost is negligible, compared to failure of vital equipment, loss of materials, wasted time and expensive repairs. Application can be made quickly. For full details, write us about your needs today.

IMMEDIATE DELIVERY

AMERCOAT DIVISION

American Pipe & Construction Co.
Dept. 4B
P. O. Box 3428, Terminal Annex
Los Angeles 54, California

Crowell heads division

Alec M. Crowell, director of the Mississippi Oil and Gas Engineering Committee, has been named to direct activities of the conservation and reserves unit of the recently created Oil and Gas Division of the U. S. Department of the Interior. The selection was made by Secretary of the Interior J. A. Krug and Ralph K. Davies, acting director of the new division. Crowell is to take over his duties in Washington either December 15 or January 1, depending on when he can finish up his work with the Mississippi committee.

Alec M. Crowell

In asking for Crowell's release by the Mississippi committee, **Davies pointed out** that the new division of the interior department will have as one of its principal branches a conservation and reserves unit, which Crowell will head, to handle from the federal standpoint problems of petroleum conservation and the provision of adequate national reserves. This is a field, he said, in which he is sure the federal government can do some effective work in the public interest, work that will redound to the benefit of the oil industry as well.

A native of Monroe, North Carolina, Alec Crowell has been in the oil country continuously for the last 21 years. His career began in 1925 with the Empire Oil and Refining Company (Cities Service) at Bartlesville, Oklahoma, and he served that company as a petroleum engineer for five years in the Mid-Continent area.

Early in 1930 he went to California for the Del Rey Oil Company of Los Angeles and remained there until the latter part of 1932 when he returned to Amarillo, Texas, for the Shamrock Oil and Gas Company.

From mid-1933 until early 1938 he was employed by the Oil and Gas Division of the Texas Railroad Commission with headquarters at Austin. He was successively chief natural gas engineer and director of field engineering and research. Early in 1938 he was loaned to the State of Arkansas to organize the Arkansas Oil and Gas Commission. This commission is referred to in industry as the model regulatory agency.

The oil and gas operators of Mississippi employed him in January of 1945 to organize the Mississippi committee.

Expands facilities

Expansion of plant facilities is announced by Allied Steel Products Corporation, Tulsa, Oklahoma, with the re-location of its plant on a 10-acre site at 2110 North Lewis.

Construction of the modern plant and installation of the latest type fabricating equipment are now virtually completed, according to E. C. Hinkefent, president.

Davison general manager

W. H. Davison

James A. Lewis, president of Core Laboratories, Inc., Dallas, Texas, has announced the promotion of W. H. Davison to vice president and general manager. Davison, formerly assistant to the president, will continue to maintain his office in Core Lab's main building, Dallas.

WANTED: Graduate engineer with at least 5 years experience with oil refinery practices for position as assistant to general foreman of oil gas making plant. Must have theoretical knowledge of oil cracking reactions and practical experience with operation and maintenance of plant equipment. Southern California. $300-$400 month. Age 30-40. State present salary, education and experience. Address Box 56, c/o *The Petroleum Engineer*, P. O. Box 1589, Dallas, Texas.

MECHANICAL ENGINEER
MUD ENGINEER

For research and development in problems connected with methods of drilling for oil, a major oil company requires the services of a well-qualified mechanical engineer and a well-qualified mud engineer as permanent staff members.

Mechanical engineer should have inventive and design ability and practical oil field drilling experience to be considered.

A mud engineer is needed for development work and should have had considerable laboratory and field experience with oil-base and other low filtrate loss muds.

For the laboratory and shop phases of the work, a modern and expanding Southwestern laboratory furnishes complete facilities and pleasant surroundings.

Time will be saved in consideration of applicants if their initial communications give full information.

Reply to Box 57, c/o The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.

Sales engineering positions—men 32 years or younger wanted to train for sales work. Some knowledge of oil production and college engineering training required. Please give brief details of qualifications. Address Box 55, c/o *The Petroleum Engineer*, P. O. Box 1589, Dallas, Texas.

WANTED FOR FOREIGN SERVICE

REFINERY SUPERINTENDENT

We want a man of wide experience in topping, cracking, treating and all other phases of modern oil refinery operations, enabling him to take full charge of a large, complete refinery. Technical ability required and with it, exceptional initiative, executive ability and resourcefulness.

CHIEF ENGINEER

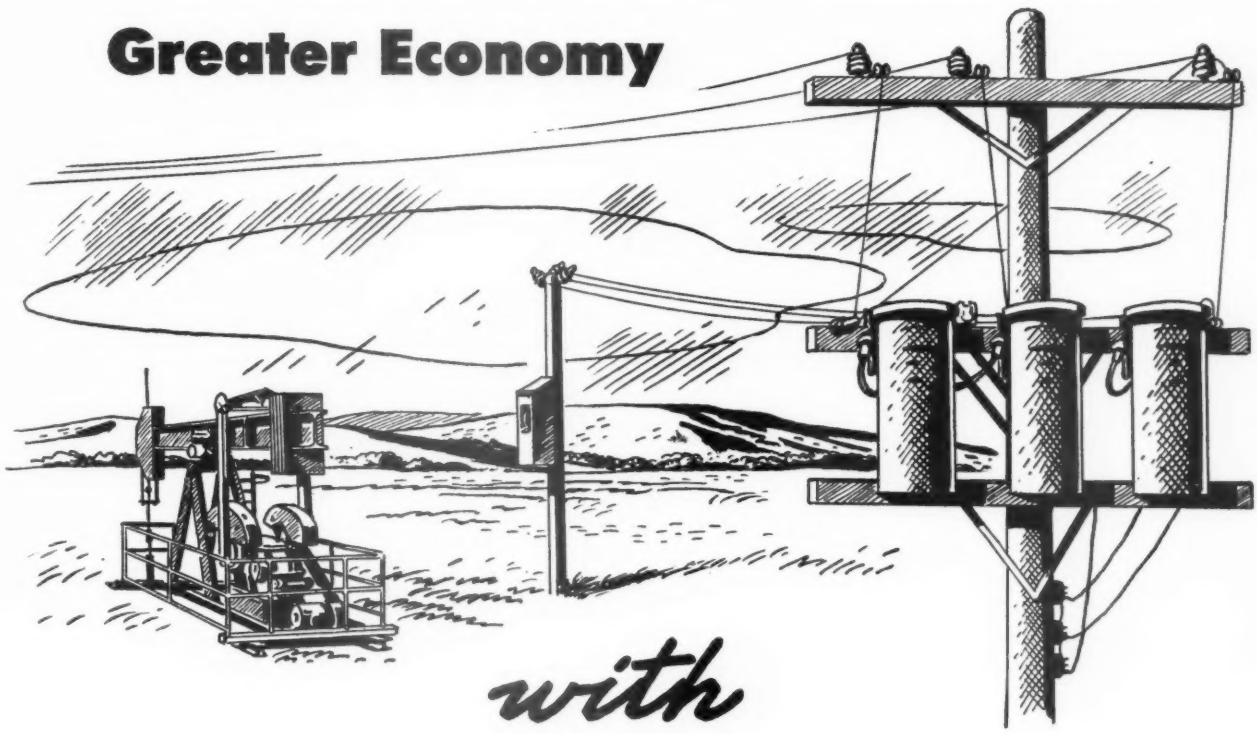
Must have wide and varied experience which qualifies him to take full charge of construction maintenance and process engineering of a large, complete oil refinery. Exceptional initiative, executive ability and resourcefulness required.

MARINE TERMINAL MANAGER

Thoroughly experienced in all phases of marine movements of petroleum products and the design, construction, operation and maintenance of a marine terminal.

Address Box 51
c/o THE PETROLEUM ENGINEER
P. O. Box 1589 Dallas, Texas

Increased Efficiency
Greater Economy



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LOW-COST ELECTRIC POWER

Electric ★ POWER OFFERS

SIMPLICITY
DEPENDABILITY
FLEXIBILITY
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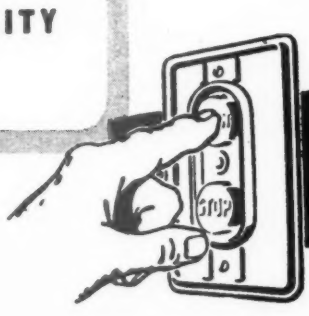
When your lease goes all-electric, you can be certain of maintaining allowable production at low cost. There is no shortage of electric power, *and it costs you less than before the war.*

Day in . . . day out, trouble-free performance has convinced operators that electric power is best.

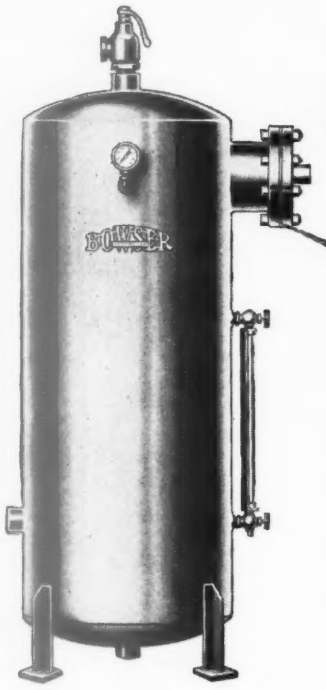


HOUSTON LIGHTING & POWER COMPANY

The New— BOWSER

ESTABLISHED 1885

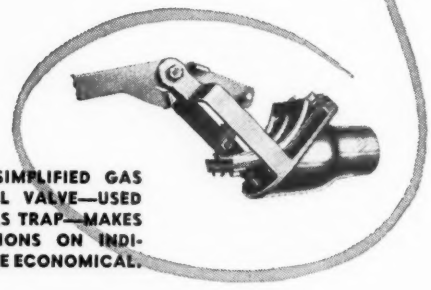
GAS TRAP . . . for OIL WELLS



WITH NEW..SIMPLIFIED GAS AND OIL CONTROL VALVE...

- Eliminates Crude Spill-over into Gas Line
- No Packing Glands
- Operates on Vacuum or Pressure
- No Metal-to-Metal Seats
- No Grinding or Reseating
- Positive Action
- Nothing to Get Out of Order

FIG. 426 GAS TRAP



THIS PATENTED, SIMPLIFIED GAS AND OIL CONTROL VALVE—USED IN THE FIG. 426 GAS TRAP—MAKES METER INSTALLATIONS ON INDIVIDUAL WELLS MORE ECONOMICAL.

The new Bowser Fig. 426 Gas Trap efficiently separates gas from oil in individual well installations or as a central unit for small lease operations.

It is an important part of the complete Bowser Automatic Well-Check System when combined with the Bowser Proportional Sampler and Special Oil Well Meter.

Write today for complete details on the new Bowser Gas Trap.

BOWSER, INC., 1329 Creighton Avenue, Fort Wayne 2, Indiana

LIQUID CONTROL SPECIALISTS SINCE 1885

Addresses Dallas Nomads

Colonel George E. B. Peddy, attorney of Houston, Texas, was guest speaker at the cocktail party and buffet supper December 13 of the Dallas chapter of Nomads. Colonel Peddy was well qualified to address a group of world travelers such as the Nomads. He resigned from the law firm with which he was connected in September, 1942, to volunteer for service in World War II. He was in charge of Office Procurement Service of the Eighth Service Command at Dallas, Texas, from November, 1942, to May, 1943, when he entered the School of Military Government at the University of Virginia. Upon completion of the course he served in the military government of North Africa and Italy, participated in the invasion of Normandy and all campaigns in the European Theater. He was promoted to lieutenant colonel November 15, 1944, during the siege of Metz and awarded the Bronze Star and the Croix de Guerre. From July to October, 1945, he was legal officer and deputy military government officer of the City of Frankfurt, Germany, He was discharged from the army in March of this year and returned to law practice.

Col. Geo. E. B. Peddy

Named vice presidents

A. E. Walker, president of The National Supply Company, Pittsburgh, has announced the appointment of two new vice presidents of National Supply Export Corporation, a company subsidiary. Thomas J. Walne, who has been division engineer of the corporation, will be vice president and general manager, and E. M. Gretzler will be vice president in charge of export sales. The corporation, with offices at 30 Rockefeller Plaza, New York, represents the company in foreign sales of oil field machinery and equipment, including pipe, drilling rigs, and diesel engines.

The promotions became effective December 1 upon the retirement of L. V. Boggs. Mr. Boggs, who established the export department that was later incorporated as the subsidiary of National Supply, will remain with the corporation in an advisory capacity.

Walne, the new general manager, studied engineering at Baylor University and the University of Oklahoma. He has been in the oil industry since 1923 and from 1936 until he joined The National Supply Company in 1943 was head of the oil field machinery division of an engineering firm in Port-of-Spain, Trinidad. For two years he was in the Toledo offices of the company and last year became division engineer of the National Supply Export Corporation.

Gretzler, vice president in charge of export sales, joined The National Supply Company in 1919 upon his graduation from Carnegie Institute of Technology. In 1927 he was manager of the company's branch in the Ploesti oil field in Romania, returning to New York in 1937 to become manager of export sales.

To Rocky Mountains

R. C. Buchanan, formerly of the Cameron Iron Works' Houston sales department, has been appointed salesman for the Rocky Mountain district with headquarters at 356 North Wolcott Street, Casper, Wyoming.

Before joining the Cameron organization

in 1944, Buchanan had acquired several years' drilling experience with a major producing company on the Gulf Coast and later was employed as a cutting and fishing tool operator for a service company. During the war he enlisted with the Army Engineers.

Opens new store

Announcement has been made by the Republic Supply Company of the official opening of its newest supply store at 1641 Pine Street, Abilene, Texas. E. E. Copeland, who has represented Republic in the Fort Worth and Shreveport areas for many years, is Abilene store manager.

With the opening of this new store, Republic now serves the oil industry from 50 sales and service points situated in the centers of activity throughout Arkansas, Illinois, Indiana, Kansas, Louisiana, Mississippi, New Mexico, Oklahoma and Texas. Headquarters for the company are maintained in Houston.

Adds to facilities

E. B. Badger and Sons Company, with offices in Boston, New York and San Francisco, announces the following additions to its facilities serving the petroleum, petrochemical, and chemical industries.

The re-establishment of E. B. Badger and Sons (Great Britain) Ltd. with offices at 2 Great Winchester St., London, E. C. 2, England. J. T. T. Robinson is director and general manager.

The establishment of a Brazilian company, Badger Servicos Tecnicos de Engenharia S. A., which will open offices about the first of the year at Rua Buenos Aires 135, Rio de Janeiro, Brazil. The officers of this company include Dr. Roger H. Newton, director-president; Ernest V. Owen, director-technical; and Dr. Eduardo Guinle Filho, director-financial.

The appointment of Fluor-Lewis and Company comprised of J. S. Fluor and Milton Lewis, as its western United States representative with offices at 416 Petroleum Building, 714 West Olympic Boulevard, Los Angeles 15, California.

Acquires Ohmer Corp.

Purchase of the Ohmer Corporation of Dayton, Ohio, by the Rockwell Manufacturing Company, Pittsburgh, has been announced by Colonel Willard F. Rockwell, board chairman and president.

J. Allen Harlan, who has served as president of the Dayton concern for the last year, will remain with the new ownership as vice president. The company will continue to operate as the Ohmer Corporation, a wholly owned subsidiary of Rockwell Manufacturing Company, and maintain plant and headquarters in Dayton.

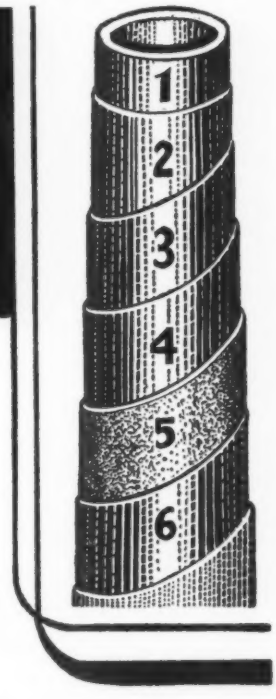
N. J. Kenney of Pittsburgh has been elected president of the Ohmer Corporation by the reorganized board of directors. He plans to move to Dayton immediately. Kenny was formerly president of the National Meter Company, Brooklyn, New York. Following the amalgamation of National Meter with Rockwell interests in 1941, Kenny has served to date as assistant to Colonel Rockwell, the president.

The new Ohmer board of directors is as follows: Colonel Willard F. Rockwell, chairman; N. J. Kenny; W. F. Rockwell, Jr.; J. A. Harlan; E. W. Meyers; F. J. Schnacke, and M. J. Carl.

Other officers are: W. F. Rockwell, Jr. and J. Allen Harlan, vice presidents; E. W. Meyers, secretary-treasurer.

SEE PAGE 2

Quality and Price EQUAL SERVICE RENDERED



We at HILL, HUBBELL with every modern up to the minute mechanical facility for precision pipe protection, analyze our position in the steel pipe processing field and its meaning to *YOU* who rely on us to protect *YOUR* under ground investment.

Mindful of raising labor and material costs we refuse to jeopardize the quality of our workmanship. We have but one standard. High quality—with prompt delivery as promised.

1 CLEANED PIPE
2 PRIMER
3 FIRST HOT COAT
4 SECOND HOT COAT
5 ASBESTOS FELT
6 THIRD HOT COAT

Typical installation of HILL, HUBBELL coated and wrapped 12¾" OD gas line delivered and installed on schedule.

Hill, Hubbell and Company
Division of GENERAL PAINT CORPORATION
3091 MAYFIELD RD. CLEVELAND, OHIO

Illustration shows typical application being made to salt water disposal tubing by Green Contracting and Engineering Co., Inc., Wichita, Kansas.

GET POSITIVE PROTECTION WITH AMERCOAT

Ravages of corrosion send millions of dollars worth of pipe and other costly equipment to the junk pile before its time. AMERCOAT produces a long-lasting, non-brittle coating that gives positive corrosion protection. In addition, there is negligible reduction of inside diameters and much lower friction loss.

Since AMERCOAT is unaffected by salt water, crude, acids, alkalies and sulfur compounds, it is being successfully used for the protection of:

Production Tubing • *Injection Well Tubing* • *Chokes* • *Disposal Tubing Packers* • *High Pressure Gate Valves Submerged Pumps and Motors* • *Sour Crude Tanks* • *Line Pipe*

Cost is negligible, compared to failure of vital equipment, loss of materials, wasted time and expensive repairs. Application can be made quickly. For full details, write us about your needs today.

IMMEDIATE DELIVERY

Amercoat Protective Coatings

AMERCOAT DIVISION

American Pipe & Construction Co.
Dept. 4B
P. O. Box 3428, Terminal Annex
Los Angeles 54, California

Crowell heads division

Alec M. Crowell, director of the Mississippi Oil and Gas Engineering Committee, has been named to direct activities of the conservation and reserves unit of the recently created Oil and Gas Division of the U. S. Department of the Interior. The selection was made by Secretary of the Interior J. A. Krug and Ralph K. Davies, acting director of the new division. Crowell is to take over his duties in Washington either December 15 or January 1, depending on when he can finish up his work with the Mississippi committee.

Alec M. Crowell

In asking for Crowell's release by the Mississippi committee, Davies pointed out that the new division of the interior department will have as one of its principal branches a conservation and reserves unit, which Crowell will head, to handle from the federal standpoint problems of petroleum conservation and the provision of adequate national reserves. This is a field, he said, in which he is sure the federal government can do some effective work in the public interest, work that will redound to the benefit of the oil industry as well.

A native of Monroe, North Carolina, Alec Crowell has been in the oil country continuously for the last 21 years. His career began in 1925 with the Empire Oil and Refining Company (Cities Service) at Bartlesville, Oklahoma, and he served that company as a petroleum engineer for five years in the Mid-Continent area.

Early in 1930 he went to California for the Del Rey Oil Company of Los Angeles and remained there until the latter part of 1932 when he returned to Amarillo, Texas, for the Shamrock Oil and Gas Company.

From mid-1933 until early 1938 he was employed by the Oil and Gas Division of the Texas Railroad Commission with headquarters at Austin. He was successively chief natural gas engineer and director of field engineering and research. Early in 1938 he was loaned to the State of Arkansas to organize the Arkansas Oil and Gas Commission. This commission is referred to in industry as the model regulatory agency.

The oil and gas operators of Mississippi employed him in January of 1945 to organize the Mississippi committee.

Expands facilities

Expansion of plant facilities is announced by Allied Steel Products Corporation, Tulsa, Oklahoma, with the re-location of its plant on a 10-acre site at 2110 North Lewis.

Construction of the modern plant and installation of the latest type fabricating equipment are now virtually completed, according to E. C. Hinkefent, president.

Davison general manager

W. H. Davison

James A. Lewis, president of Core Laboratories, Inc., Dallas, Texas, has announced the promotion of W. H. Davison to vice president and general manager. Davison, formerly assistant to the president, will continue to maintain his office in Core Lab's main building, Dallas.

years experience with oil refinery practices for position as assistant to general foreman of oil gas making plant. Must have theoretical knowledge of oil cracking reactions and practical experience with operation and maintenance of plant equipment. Southern California. $300-$400 month. Age 30-40. State present salary, education and experience. Address Box 56, c/o *The Petroleum Engineer*, P. O. Box 1589, Dallas, Texas.

MECHANICAL ENGINEER
MUD ENGINEER

For research and development in problems connected with methods of drilling for oil, a major oil company requires the services of a well-qualified mechanical engineer and a well-qualified mud engineer as permanent staff members.

Mechanical engineer should have inventive and design ability and practical oil field drilling experience to be considered.

A mud engineer is needed for development work and should have had considerable laboratory and field experience with oil-base and other low filtrate loss muds.

For the laboratory and shop phases of the work, a modern and expanding Southwestern laboratory furnishes complete facilities and pleasant surroundings.

Time will be saved in consideration of applicants if their initial communications give full information.

Reply to Box 57, c/o The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.

Sales engineering positions—men 32 years or younger wanted to train for sales work. Some knowledge of oil production and college engineering training required. Please give brief details of qualifications. Address Box 55, c/o *The Petroleum Engineer*, P. O. Box 1589, Dallas, Texas.

WANTED FOR FOREIGN SERVICE

REFINERY SUPERINTENDENT

We want a man of wide experience in topping, cracking, treating and all other phases of modern oil refinery operations, enabling him to take full charge of a large, complete refinery. Technical ability required and with it, exceptional initiative, executive ability and resourcefulness.

CHIEF ENGINEER

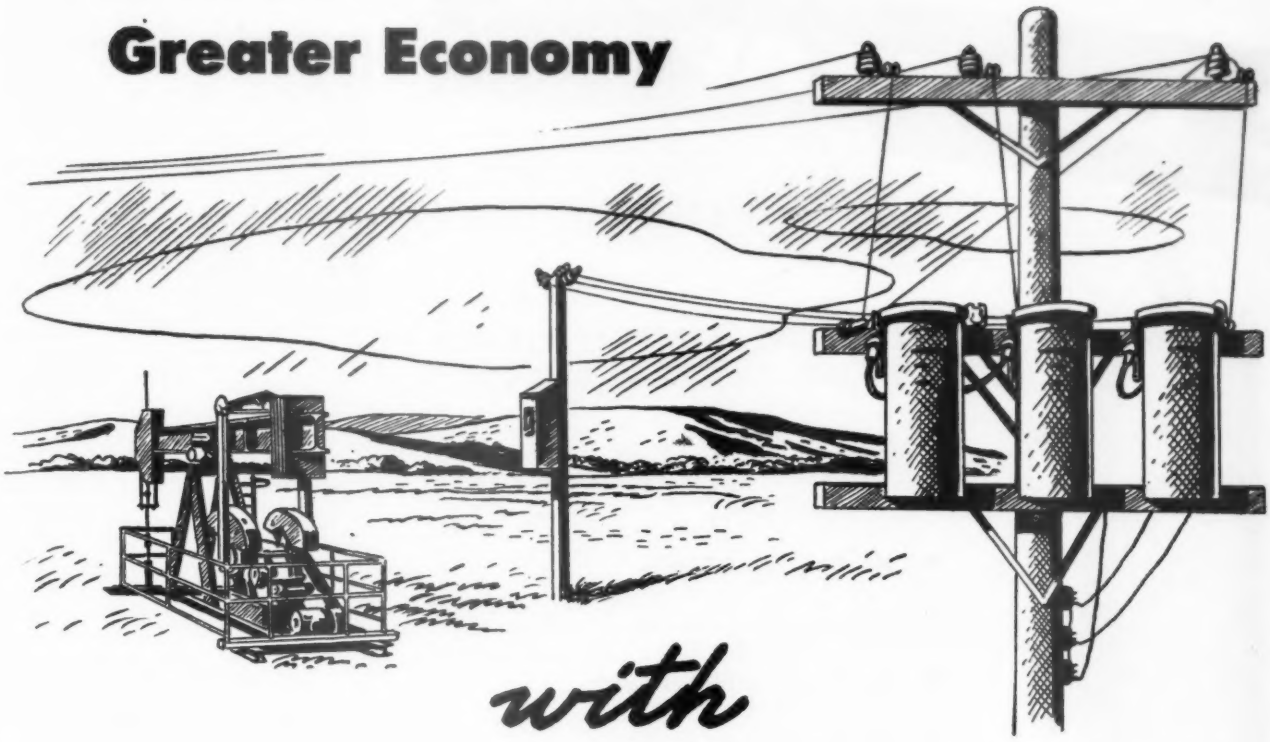
Must have wide and varied experience which qualifies him to take full charge of construction maintenance and process engineering of a large, complete oil refinery. Exceptional initiative, executive ability and resourcefulness required.

MARINE TERMINAL MANAGER

Thoroughly experienced in all phases of marine movements of petroleum products and the design, construction, operation and maintenance of a marine terminal.

Address Box 51
c/o THE PETROLEUM ENGINEER
P. O. Box 1589 Dallas, Texas

Increased Efficiency
Greater Economy



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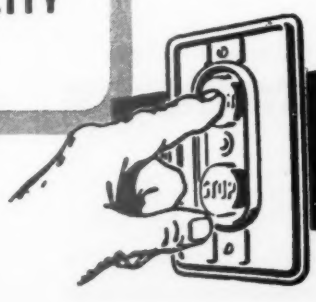
LOW-COST ELECTRIC POWER

Electric ★ POWER OFFERS

SIMPLICITY
DEPENDABILITY
FLEXIBILITY
ECONOMY
VERSATILITY

When your lease goes all-electric, you can be certain of maintaining allowable production at low cost. There is no shortage of electric power, *and it costs you less than before the war.*

Day in . . . day out, trouble-free performance has convinced operators that electric power is best.



HOUSTON LIGHTING & POWER COMPANY

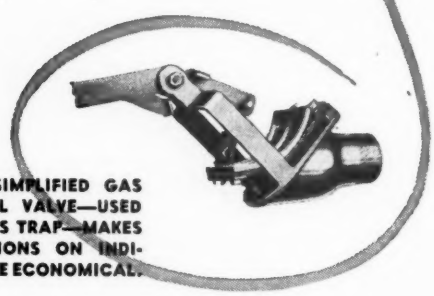
The New— BOWSER
ESTABLISHED 1885

GAS TRAP . . .
for OIL WELLS

FIG. 426 GAS TRAP

WITH NEW..SIMPLIFIED GAS AND OIL CONTROL VALVE...

- Eliminates Crude Spill-over into Gas Line
- No Packing Glands
- Operates on Vacuum or Pressure
- No Metal-to-Metal Seats
- No Grinding or Reseating
- Positive Action
- Nothing to Get Out of Order



THIS PATENTED, SIMPLIFIED GAS AND OIL CONTROL VALVE—USED IN THE FIG. 426 GAS TRAP—MAKES METER INSTALLATIONS ON INDIVIDUAL WELLS MORE ECONOMICAL.

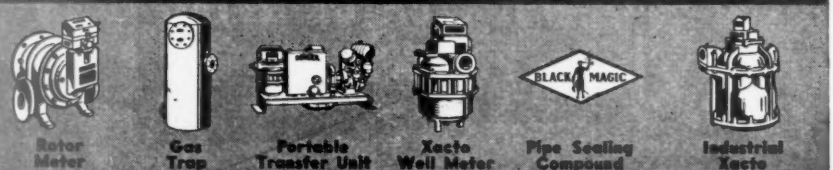
The new Bowser Fig. 426 Gas Trap efficiently separates gas from oil in individual well installations or as a central unit for small lease operations.

It is an important part of the complete Bowser Automatic Well-Check System when combined with the Bowser Proportional Sampler and Special Oil Well Meter.

Write today for complete details on the new Bowser Gas Trap.

BOWSER, INC., 1329 Creighton Avenue, Fort Wayne 2, Indiana

LIQUID CONTROL SPECIALISTS SINCE 1885



Addresses Dallas Nomads

Colonel George E. B. Peddy, attorney of Houston, Texas, was guest speaker at the cocktail party and buffet supper December 13 of the Dallas chapter of Nomads. Colonel Peddy was well qualified to address a group of world travelers such as the Nomads. He resigned from the law firm with which he was connected in September, 1942, to volunteer for service in World War II. He was in charge of Office Procurement Service of the Eighth Service Command at Dallas, Texas, from November, 1942, to May, 1943, when he entered the School of Military Government at the University of Virginia. Upon completion of the course he served in the military government of North Africa and Italy, participated in the invasion of Normandy and all campaigns in the European Theater. He was promoted to lieutenant colonel November 15, 1944, during the siege of Metz and awarded the Bronze Star and the Croix de Guerre. From July to October, 1945, he was legal officer and deputy military government officer of the City of Frankfurt, Germany, He was discharged from the army in March of this year and returned to law practice.

Col. Geo. E. B. Peddy

Named vice presidents

A. E. Walker, president of The National Supply Company, Pittsburgh, has announced the appointment of two new vice presidents of National Supply Export Corporation, a company subsidiary. Thomas J. Walne, who has been division engineer of the corporation, will be vice president and general manager, and E. M. Gretzler will be vice president in charge of export sales. The corporation, with offices at 30 Rockefeller Plaza, New York, represents the company in foreign sales of oil field machinery and equipment, including pipe, drilling rigs, and diesel engines.

The promotions became effective December 1 upon the retirement of L. V. Boggs. Mr. Boggs, who established the export department that was later incorporated as the subsidiary of National Supply, will remain with the corporation in an advisory capacity.

Walne, the new general manager, studied engineering at Baylor University and the University of Oklahoma. He has been in the oil industry since 1923 and from 1936 until he joined The National Supply Company in 1943 was head of the oil field machinery division of an engineering firm in Port-of-Spain, Trinidad. For two years he was in the Toledo offices of the company and last year became division engineer of the National Supply Export Corporation.

Gretzler, vice president in charge of export sales, joined The National Supply Company in 1919 upon his graduation from Carnegie Institute of Technology. In 1927 he was manager of the company's branch in the Ploesti oil field in Romania, returning to New York in 1937 to become manager of export sales.

To Rocky Mountains

R. C. Buchanan, formerly of the Cameron Iron Works' Houston sales department, has been appointed salesman for the Rocky Mountain district with headquarters at 356 North Wolcott Street, Casper, Wyoming.

Before joining the Cameron organization

in 1944, Buchanan had acquired several years' drilling experience with a major producing company on the Gulf Coast and later was employed as a cutting and fishing tool operator for a service company. During the war he enlisted with the Army Engineers.

Opens new store

Announcement has been made by the Republic Supply Company of the official opening of its newest supply store at 1641 Pine Street, Abilene, Texas. E. E. Copeland, who has represented Republic in the Fort Worth and Shreveport areas for many years, is Abilene store manager.

With the opening of this new store, Republic now serves the oil industry from 50 sales and service points situated in the centers of activity throughout Arkansas, Illinois, Indiana, Kansas, Louisiana, Mississippi, New Mexico, Oklahoma and Texas. Headquarters for the company are maintained in Houston.

Adds to facilities

E. B. Badger and Sons Company, with offices in Boston, New York and San Francisco, announces the following additions to its facilities serving the petroleum, petrochemical, and chemical industries.

The re-establishment of E. B. Badger and Sons (Great Britain) Ltd. with offices at 2 Great Winchester St., London, E. C. 2, England. J. T. T. Robinson is director and general manager.

The establishment of a Brazilian company, Badger Servicos Tecnicos de Engenharia S. A., which will open offices about the first of the year at Rua Buenos Aires 135, Rio de Janeiro, Brazil. The officers of this company include Dr. Roger H. Newton, director-president; Ernest V. Owen, director-technical; and Dr. Eduardo Guinle Filho, director-financial.

The appointment of Fluor-Lewis and Company comprised of J. S. Fluor and Milton Lewis, as its western United States representative with offices at 416 Petroleum Building, 714 West Olympic Boulevard, Los Angeles 15, California.

Acquires Ohmer Corp.

Purchase of the Ohmer Corporation of Dayton, Ohio, by the Rockwell Manufacturing Company, Pittsburgh, has been announced by Colonel Willard F. Rockwell, board chairman and president.

J. Allen Harlan, who has served as president of the Dayton concern for the last year, will remain with the new ownership as vice president. The company will continue to operate as the Ohmer Corporation, a wholly owned subsidiary of Rockwell Manufacturing Company, and maintain plant and headquarters in Dayton.

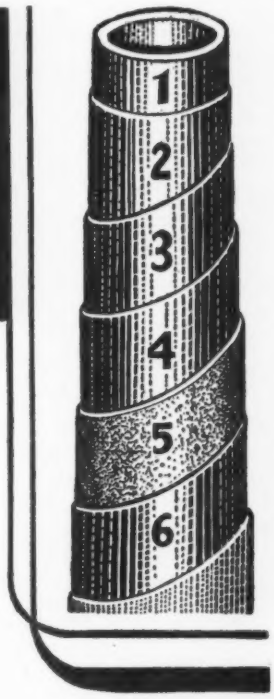
N. J. Kenney of Pittsburgh has been elected president of the Ohmer Corporation by the reorganized board of directors. He plans to move to Dayton immediately. Kenny was formerly president of the National Meter Company, Brooklyn, New York. Following the amalgamation of National Meter with Rockwell interests in 1941, Kenny has served to date as assistant to Colonel Rockwell, the president.

The new Ohmer board of directors is as follows: Colonel Willard F. Rockwell, chairman; N. J. Kenny; W. F. Rockwell, Jr.; J. A. Harlan; E. W. Meyers; F. J. Schnacke, and M. J. Carl.

Other officers are: W. F. Rockwell, Jr. and J. Allen Harlan, vice presidents; E. W. Meyers, secretary-treasurer.

SEE PAGE 2

Quality and Price
EQUAL SERVICE RENDERED



We at HILL, HUBBELL with every modern up to the minute mechanical facility for precision pipe protection, analyze our position in the steel pipe processing field and its meaning to *YOU* who rely on us to protect *YOUR* under ground investment.

Mindful of raising labor and material costs we refuse to jeopardize the quality of our workmanship. We have but one standard. High quality—with prompt delivery as promised.

1 CLEANED PIPE
2 PRIMER
3 FIRST HOT COAT
4 SECOND HOT COAT
5 ASBESTOS FELT
6 THIRD HOT COAT

Typical installation of HILL, HUBBELL coated and wrapped 12¾" OD gas line delivered and installed on schedule.

Hill, Hubbell and Company
Division of GENERAL PAINT CORPORATION
5091 MAYFIELD RD. CLEVELAND, OHIO

Blackmer sales manager

Arthur E. Jacobs has been appointed vice president and sales manager of Blackmer Pump Company, Grand Rapids, Michigan, according to an announcement by B. L. Gordon, president of the company.

Jacobs was formerly general sales manager of the pump division of George D. Roper Corporation, Rockford, Illinois, and has, for more than 30 years, been engaged in the design, production, and marketing of industrial equipment, chiefly pumps, hydraulic machinery, and machine tools. His work in the rotary pump field has been nationally recognized and he is now serving as chairman of the Rotary Pump Section of the Hydraulic Institute, which is the national association of industrial pump manufacturers.

Among mill supply distributors and users of industrial pumping equipment, Jacobs is widely known for the thoroughness of his sales and service policies and for his merchandising ability.

Jacobs received his training in mechanical engineering at Lewis Institute of Technology and Chicago Technical College, and was associated with the Ingersoll Milling Machine Company, Rockford, Illinois, in design, methods, and sales engineering before joining the Roper company. He assumed his duties with the Blackmer Company on November 1, and will move to Grand Rapids.

Moves offices

The Project Engineering Company has moved its general offices to new and enlarged quarters at 115 Fulton Street, New York 7, New York. Work on four oil refinery units is now in progress at the new offices. The company is operating under James P. O'Donnell, manager, and Guy M. Barbolini, chief engineer.

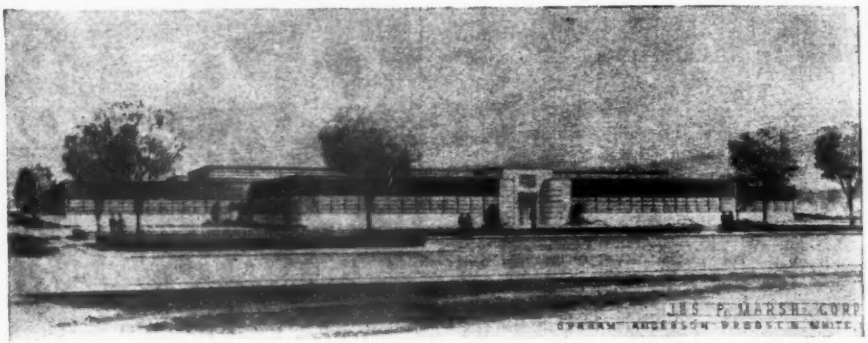
New plant for Jas. P. Marsh Corporation

An announcement to the effect that C.P.A. approval has been given to the Jas. P. Marsh Corporation, Chicago, Illinois, well known manufacturer of industrial instruments and heating specialties, to begin immediate construction of a new factory and office building comes from Barrett Scudder, president of the company. He states that the new building will be erected on a five-acre tract of land situated at Howard Street and St. Louis Avenue in Skokie, Illinois (Chicago suburb).

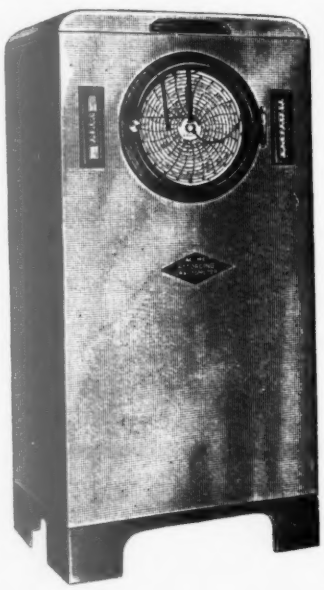
According to Scudder, the building will incorporate the latest in industrial building design and construction throughout. It will cover an area of approximately 100,000 sq. ft. and will be a one-story unit providing ample working facilities and the advantages of having the factory on one level. The building is to be constructed of concrete and steel with cut stone facings, with a monitor type roof over the factory to obtain the maximum of natural light for ideal working conditions.

The general offices will be of modern design, according to company officials. Among other features, it will be air-conditioned throughout and the latest method of soundproofing and lighting will be employed.

One of the interesting features of the building will be the heating system. As manufacturers of heating equipment, Marsh Corporation is vitally interested in the research and compilation of definite facts on heat control. Therefore, the new building is to be used as the "guinea pig" for extensive research on heating methods.



Present offices at 15 Maiden Lane will be maintained and mail may be addressed to either address. The fabrication shop at Long Island City, New York, is also operated by the company under the management of Barbolini.

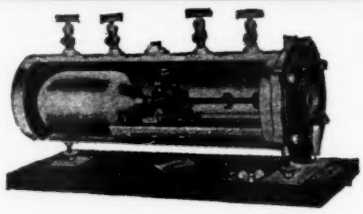


AC-ME RECORDING GRAVITOMETER

COMPLETE VISIBILITY
EXTREMELY SENSITIVE

This instrument accurately records the changing gravity of gas and automatically corrects for variation in barometric pressure and temperature. Sturdy construction and simplicity of operation contribute to accurate operation with a minimum of maintenance.

The instrument does not contain rotating parts thereby eliminating a major source of wear. The accuracy and practicability of Refinery Supply Company equipment are the result of scientific and sound manufacturing procedures combined with materials of proven integrity.



GAS GRAVITY BALANCE

Gives dependable and accurate results on wet gas, dry natural gas and artificial gas. In determining the specific gravity of gas, will give results that can be checked within 3 points in the fourth place.

Each unit is completely equipped with needle valves and carrying case.

Designed for laboratory, plant and field.

Write for Catalog No. 30-A

THE REFINERY SUPPLY CO.

Main Office and Plant

621 E. 4th Street TULSA 3, OKLAHOMA Ph. 4-8144, L.D. 581

— Houston Office Temporarily Discontinued —

Machinery department

Howard Supply Company announces the reorganization of its forces with the special institution of a machinery department, the function of which will be to handle sales and service on power drilling equipment from 150 to 1325 hp., and a complete line of production machinery and supplies. Appointed manager of the new department is N. W. Wickersham, a member of Perkins Cementing Company for 14 years; with Chanslor Canfield Midway Oil Company for 8 years,

N. W. Wickersham

B. N. Cox

and widely known in the California petroleum industry as a well qualified and competent engineer. Simultaneously appointed assistant manager of machinery is B. N. Cox, who has been with Howard Supply Company for the last eight years.

A.P.I. chapter meeting

The Los Angeles Basin chapter of the American Petroleum Institute, Division of Production, held a lively meeting at Long Beach on November 12, with a fine attendance, although a violent rainstorm did its best to dampen the proceedings. With Vernon Shepherd, Eastman Oil Well Surveying Company, in the chair, the gathering was treated to a symposium on completion practices. The first paper was entitled, "Effect of Drilling Mud on Cementing and Completion Practices," and was delivered by H. E. Radford, mechanical engineer, Shell Oil Company, Ventura. The second was by K. A. Wright, B & W Company, on the related topic: "Investigation Into Placement of Cement Slurries in Oil Well Cementing."

After a spirited discussion of these two papers and completion practices generally, the annual election was held, and the following results were announced: Chairman for 1947, L. R. Rogers, Superior Oil Company, Torrance; vice chairman, Homer Woodruff, The Texas Company; secretary-treasurer, Ward Tennis, International Cementers; assistant secretary-treasurer, Ray Webb, Sperry Sun.

General manager assn.

Election of Charles E. Simons of Austin as vice president and general manager of the Texas Mid-Continent Oil and Gas Association was announced from association headquarters in Dallas by Fred W. Shield, president. Simons, who will assume his duties January 1, succeeds the late George C. Gibbons.

Chas. E. Simons

For the last three and one-half years, Simons has been executive vice president of the Texas Good Roads Association.

TOO BIG FOR RISKS FOR HAND EXTINGUISHERS

Pyrene AIR FOAM

Systems Produce Hundreds or Thousands of Gallons of Foam per Minute

Portable fire extinguishers are invaluable for putting out little fires, but in the oil business an inferno can break loose in a few seconds—one spark . . . and a whole tank is in flames. When that happens, you've got to have something quick and plenty of it. Pyrene mechanical Air Foam Systems deliver hundreds or thousands of gallons of fire-blanketing foam in a hurry. Flames can't withstand such a flood of heat-resistant foam.

One gallon of Pyrene Foam Compound and 20 gallons of water, combined with air, produce at least 320 gallons of foam in one minute. Such a high expansion ratio insures a quick, free-flowing layer of foam over a large area in the shortest time.

Air Foam Systems are Pyrene's answer to the petroleum industry's immense needs for modern fire protection. A Pyrene engineer will be glad to help you plan a complete Air Foam System for your particular hazard. Write for *Air Foam*, a booklet on fighting flammable liquid fires.

Pyrene Manufacturing Company
NEWARK 8 NEW JERSEY
Affiliated with the C-O-Two Fire Equipment Co.

When do oil men say a light is JUSTRITE?

Before men in the oil industry give a light or lantern their approval it must meet certain specifications:

It must be safe. Fire is a constant menace in oil fields.

Justrite Lantern No. 44-S is approved for safety by Underwriters' Laboratories, Inc., and the U. S. Bureau of Mines.

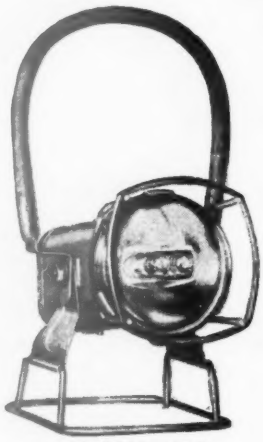
It must be sturdy—built to take hard usage.

All Justrite products are made of the finest materials, to precision standards.

It must be satisfactorily designed for its purpose.

Justrite Lantern No. 44-S is adjustable to any position—can be hung up, stood up or carried on arm. Body of lantern swings on center pivot, permitting beam to be focused up, down or at any angle desired. Twin bulbs assure against light failure. "Kick-out" bulb sockets immediately eject a broken bulb.

Its steadily mounting sales in the industry prove that this Justrite Lantern No. 44-S ranks A-1 with oil men everywhere.



Model No. 44-S

Available now—from your regular supplier!

JUSTRITE MANUFACTURING COMPANY
2063 N. Southport Ave., Dept. G-3, Chicago, Illinois

Moves offices

W. E. Sievers, well-known oil tool executive, announces the moving of his offices from Whittier, California, to the Quinby Building, 650 South Grand Avenue, Los Angeles, California. Sievers recently resigned as chairman of the board of the Security Engineering Company, Inc., to devote his entire time to Sievers Industries, Inc.

Expansion program

An expansion program in the engineering department of the Blackmer Pump Company, Grand Rapids, Michigan, has been announced by B. L. Gordon, president of the company.

The new program will provide for more extensive development work on the Blackmer line of rotary pumps to meet the changing requirements of industrial pump users. The appointment of a new chief engineer and the addition of two senior engineers are announced.

John B. Caldwell, who has been identified with the development of pumps and various types of hydraulic equipment, has been named chief engineer, and L. R. DeWolf and V. A. Brunson have been appointed senior engineers.

Prior to joining Blackmer, Caldwell spent more than three years in the Navy. He was discharged last summer with the rank of lieutenant commander. A graduate of Cornell University in 1931 with a degree in mechanical engineering, Caldwell spent a number of years in Buffalo, New York, as general manager of a large metal fabricating concern. Subsequently, he was in New York City for about four years in charge of manufacturing operations for Air Reduction Aircraft Instrument Division.

cut maintenance costs with AIRETOOL tube cleaners

The simplicity of construction in all Airetool Tube Cleaners assures lower maintenance costs . . . and cleaner tubes for refineries. All vital wearing parts in Airetool cleaners are easily replaceable on the job.

Airetool's New Form cutters eliminate tracking and give tubes a clean, smooth surface. Airetool's motors, with Balanced Rotor and Power Seal, deliver more power—they make hard jobs look easy. The motors are air and steam or water driven for cleaners for all types of tubular construction—straight or curved—in sizes from 1/4" to 24".

Write Dept. EN for bulletins on tube cleaners and expanders especially designed for use in refineries.

Illustrated is the P type head mounted on a "3000" series motor, air or steam driven. It is designed for straight tubes from 2¼" to 4¾" I.D.

AIRTOOL EXPANDERS

Airetool manufactures a complete line of tube expanders . . . meeting every need of the modern refinery. Special heat-treated alloy steels assure a uniform grain and hardness.

AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD, OHIO

Cameron appoints Davis division manager

Roy Davis

Cameron Iron Works, Houston, Texas, announces the appointment of Roy Davis as manager of sales for the West Texas district. Davis has already moved his family to Midland where he has established headquarters.

Prior to his transfer to West Texas, Davis was a member of the Cameron sales and field service staff in Houston since 1940. He is a graduate of Rice Institute and was employed in the drilling department of Gulf Oil Corporation before joining Cameron Iron Works.

Davis will be assisted by A. A. O'Conner, who was recently transferred from Natchez, Mississippi, to Odessa, Texas, and M. L. Hooks, who recently rejoined the company and will operate from Hobbs, New Mexico.

Heads A.I.M.E.

Able engineers from every division of the mineral industry make up a well-rounded roster of the officers who will direct the activities of the American Institute of Mining and Metallurgical Engineers during the coming year. Clyde E. Williams, director of the Battelle Memorial Institute at Columbus, Ohio, was declared elected president of the Institute for 1947 at a meeting of the board of directors held in New York City. Williams was proposed for election by the unanimous vote of the nominating committee.

Dr. A. B. Parsons, secretary of the American Institute of Mining and Metallurgical Engineers, also announced the election of two vice presidents: Andrew Fletcher, vice president of the St. Joseph Lead Company, New York City; and Robert W. Thomas, general manager of the Nevada Consolidated Copper Corporation, Ray, Arizona.

Six directors also elected were: Oliver Bowles, chief of the Nonmetallic Economics Division of the U. S. Bureau of Mines, Washington, D. C.; Arthur John Blair, chief geologist of the Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama; William W. Mein, Sr., president of the Calaveras Cement Company, San Francisco; C. V. Millikan, chief production engineer for the Amerada Petroleum Corporation, Tulsa, Oklahoma; Earle E. Schumacher, chief metallurgist for the Bell Telephone Laboratories, Murray Hill, New Jersey, and John R. Suman, vice president of the Standard Oil Company (New Jersey), New York City.

Williams, the 64th president of the Institute to hold office in its 75 years of progressive existence, will be formally inducted into office at the annual meeting to be held in New York City in March, 1947.

War Veterans in Hughes school

GI Joe is doing all right with his school work in Houston, Texas, according to officials of the Hughes Tool Company, which is giving more than 700 of them a course in machine shop practices.

At the plant, which is owned and directed by Howard Hughes, aircraft designer-flyer, motion picture producer, and industrialist, the ex-soldiers are taking three hours of theory in the plant yard under the tutelage of University of Houston professors. The remaining hours of the work day is spent in the shops where the theory is applied to actual work.

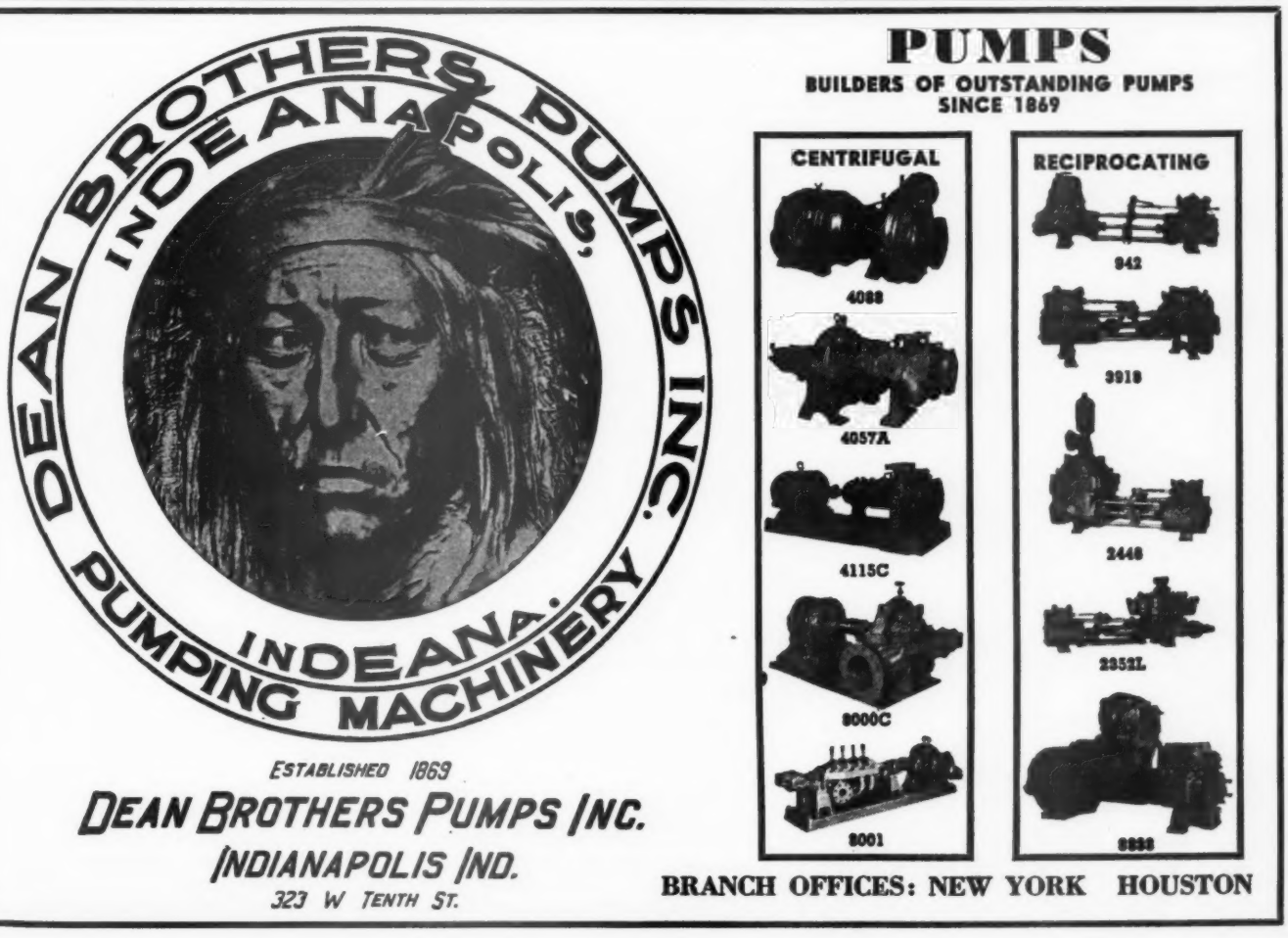
Work turned out by the GI's is running well above standards for beginners say the Hughes people who are enthusiastic about the setup.

Moves facilities

Reflecting its confidence in the continued importance of Pittsburgh as a manufacturing center, H. K. Porter Company, Inc., announces that it is moving its two Quimby Pump manufacturing operations in New Jersey to be centralized in the company's plant at 49th and Harrison streets in Lawrenceville.

The Quimby Pump Company, Inc., was established in New York in 1893 and subsequently moved to its New Jersey plants, one in Newark and one in New Brunswick.

During 1943 the Quimby Pump Company was acquired by H. K. Porter Company, Inc., and through expansion of its engineering and development work now manufactures a broad line of pumps used by industries and marine services.



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Hard ore is chosen. This gives Driocel the rugged durability to stand up under repeated (at times, violent) handling . . . to resist temperature, pressure and flow variations.

A sharp eye is kept on the presence of iron. After magnetic treatment, Driocel's iron content is controlled to 3%, or less. Drying operations can be conducted in such a manner that low-iron Driocel is unaffected by appreciable amounts of H_2S.

Rigid control continues. It insures *uniform* size of Driocel's particles, in a wide variety of meshes, and the precise activation that gives Driocel its amazing adsorptive capacity. And, with all this extreme manufacturing care, Driocel's price is substantially lower than other well known solid desiccants.

Driocel is successfully drying hydro-carbon liquids and gases, liquid organic chemicals, compressed air, electrical oils, hydrogen, hydrogen sulfide, etc. We'll welcome the opportunity to get "down to earth" on *your* drying problems. Address: Attapulgus Clay Company (Exclusive Sales Agent), Dept. J, 260 So. Broad Street, Phila. 1, Pa.

POROCEL

ACTIVATED BAUXITES • SUPPORTED CATALYSTS • CATALYST CARRIERS • ABSORBENTS AND DESICCANTS

Agricultural service manager

Ross Floyd

One of the founders of the Future Farmers of America and for many years a vocational agricultural specialist, Ross Floyd, has been appointed agricultural service manager for Continental Oil Company, Ponca City, it was announced by Harry J. Kennedy, vice president in charge of marketing.

Floyd will assume active charge of Continental Oil Company's agricultural program, which provides a broad service to those engaged in farm, ranch, livestock, and kindred agricultural pursuits, and which in the future will also stress the promotion of activities of farm youth.

Floyd joins Continental after serving the War Finance Division, U. S. Treasury Department, Washington, D. C., as western agricultural representative. For the last eight years he had been associated with the U. S. Soil Conservation Service.

Should seek engine advice

Prospective buyers of war surplus engines should consult established distributors of the manufacturer of these engines for helpful suggestions and pertinent information about the possibility of converting them to peace-time use, according to Stewart and Stevenson Services, General Motors diesel engine distributor at Houston, Texas.

Both gasoline and diesel engines manufactured and fitted strictly for war time uses are being offered to buyers today as "ideal for commercial use" . . . "built for long life, dependable service and economic operation," etc. Although the General Motors diesel engines were built to meet military requirements, the most important of which was dependability, many of these surplus engines are not ideal for commercial use in their present form, it is stated.

In fact, it would require a great deal of conversion to make them so for most applications. Furthermore, most diesel and gasoline engines manufactured during the war were built and adjusted to the highest possible power output whereas in taking the most horsepower out of an engine, long life frequently must be sacrificed, it is pointed out.

"We can understand the desire to purchase engines as cheaply as possible," says Joe Manning of Stewart and Stevenson Services. "We do hope, however, that the parties interested in surplus engines will consult their local distributors of the engines in question before making purchases of such equipment. By doing so, they will obtain invaluable advice concerning a given conversion to a particular installation, advice that may save them considerable grief later on. To put it bluntly, they should know what they are up against in connection with the conversion of such material to their uses so that they may proceed with their eyes open."

L. A. Nomads hear McConnell

Despite the counterattraction offered by the API convention in Chicago, Los Angeles Nomads' monthly meeting at the Clark Hotel on November 13 was well attended, and boasted an especially large roster of foreign visitors. Bill Bettis presided, and after a short business session, presented Phil McConnell of Arabian-American Oil Company, who gave an interesting account of the difficulties of operation in a country far removed from sources of equipment and supply, peopled with a race having entirely different standards of education, and operating in areas that are principally notable for shifting sand dunes that really shift.

The speaker told of the intense effort that is being made by the oil companies to fit as unobstrusively as possible into an unusual foreign environment, to help the Saudi Arabians to improve their national health, and to institute such local educational and other socially elevating agencies as are approved by the native populace. He told of the difficulties of drilling, particularly emphasizing that the occasional cave-in of large hunks of limestone behind the bit, often make it necessary to indulge in a two-way operation, in which it is more difficult to drill back out than to drill farther down.

Production, to the contrary, presented no particular worries. Wells produce in gratifying quantity, and can be turned on or shut off at will, without danger to the producing formation. The gas accompanying the oil is rich in sulphur compounds, however, and is extremely toxic, so that it becomes necessary to avoid leaks at all costs, or to patch them up immediately they are discovered, in order to obviate the possibility of accidents.

Among the foreign guests present were George Akers, National Mining Corporation, Ltd., Trinidad, BWI; N. J. Alleman, E. R. Kelly, and Kuhn Calvert, Attock Oil Company, Ltd., India; B. L. Coker, C. H. Major, Danish-American Exploration Company, Copenhagen, Denmark; T. A. Connor, R. L. Connor, Jack Walsh, John E. Sligh, Harry D. Huskey, Fred C. Lay, C. H. Strickland, and C. M. Williams, Iraq Petroleum Company, Ltd., Iraq; Phil McConnell and C. G. Webb, Arabian-American Oil Company, Saudi Arabia; Warren

L. Ellison, The Texas Company, Colombia; S. J. Liu, C. K. Suez and H. S. Yao, Chinese Petroleum Corporation, Shanghai, China; Walter L. Little, Tropical Oil Company, Colombia; J. D. Lederman and G. Salvy, Societe Nationale Des Petroles, du Languedoc, Mediterranean, and Spence T. Taylor, Socony Vacuum Oil Company, Venezuela.

Tenth year of catalyst manufacturing

An important milestone in the progress of catalytic refining was passed when Houdry Process Corporation completed its tenth year of catalyst manufacturing recently, Arthur V. Danner, Houdry executive vice president has pointed out.

Ten years ago, a group of 21 picked Houdry technicians began the manufacture of the first commercial catalyst to be used in catalytic cracking. Under the supervision of A. R. Worrall, manager of Houdry's extensive catalyst-manufacturing facilities in Marcus Hook, Pennsylvania, and Paulsboro, New Jersey, this group of pioneers filled the first order for catalyst for the Sun Oil Company's fixed-bed plant, which began operations in early 1937. This initial order called for 200,000 litres of a hydrated silicate of alumina obtained in the form of natural clay.

One of Houdry's greatest contributions to the war effort was the development and manufacture of synthetic catalyst for catalytic cracking. In 1940 Houdry began manufacturing the first commercial synthetic catalyst to be used in catalytic cracking. This development served mightily in the production of highest quality aviation base stock providing better octane rating and higher yield per barrel of charge stock.

Originally catalyst was manufactured only in a small plant in Marcus Hook, Pennsylvania, but the demand increased to the point that new facilities were constructed in Paulsboro, New Jersey, in 1940. So important was the synthetic catalyst that plant capacity was doubled in 1941 and again in 1943. So efficient has been manufacturing procedure that never have a licensee's operations been delayed for lack of catalyst.

Of the original group of pioneers, 14 are still employed by Houdry Process Corporation. Two others died in service during the war.

Name "Flowrator" adopted

Fischer and Porter Company, Hatboro, Pennsylvania, manufacturers of variable area type flow metering instruments heretofore called "Rotameters," have recently announced adoption of the trademark name "Flowrator" to designate the product of its manufacture.

The first use of the former name Rotameter appears to have been made about 40 years ago by one of the early European manufacturers of variable area type flow rate indicators using transparent tapered tubes. This manufacturer utilized plumb-bob shape metering floats having bias notches cut into the float heads to impart a rotating motion. The rotation improved the stability of the metering floats and eliminated most of the vertical and horizontal oscillation previously encountered. In view of this rotation the name Rotameter was used even though it did not describe any essential function or operating requirement of the instrument and led to the erroneous impression on the part of many who first heard it, that the instrument measured rotation. As specialists in the manufacture of the variable area flow meters for indicating, recording, controlling, and integrating flow rate, Fischer and Porter Company have developed the new "bead-guide" metering tube and other methods of float stabilization more positive than the rotation feature. The rotating float has therefore been abandoned and the old name Rotameter has lost all significance as applied to the company's product.

Therefore Fischer and Porter Company have coined the new trademark name Flowrator to designate exclusively those variable area type flow meters built by itself. The new name has the additional advantage of only one possible pronunciation whereas the old name Rotameter could be pronounced two ways depending on the choice of syllable to be accented.

Turco sales chiefs

Appointment of L. H. Moulton to the post of national sales director and D. T. Buist as assistant national sales director, was announced recently by Ray Sanders, vice president and general manager, Turco Products, Inc., Los Angeles, California.

Fifteen years' experience in the selling of Turco's broad chemical line gives Lou Moulton excellent qualifications to direct the nationwide sales service staff. A graduate of Colorado College of Agriculture, he was well known in the dairy and allied industries for many years, joining Turco in 1931. For the last eight years he has directed Turco's eastern division from the Chicago plant office.

Dan Buist joined Turco in 1936 as a specialist with 20 years' experience in the automotive field. Transferred to the aviation division in 1939, he was promoted to district sales manager in 1943, and western zone sales manager in 1944.

New Chicago office

N. I. Malmstrom and Company announces the opening of its new office and warehouse at 30 West Washington Street, Chicago 2, Illinois.

● You get more for your money with RIDGID pipe wrenches. That special design housing simply won't warp or break in any normal use, however strenuous—as millions of users know. No laid up for housing repairs, no bother and expense. No binding of adjusting nut—it spins easily to size. Alloy jaws take hold and let go instantly. Handy pipe scale on hookjaw, comfort-grip I-beam handle. A wrench it's a pleasure to work with—ask your Supply House.

RIDGID *Compound Leverage Wrench.*

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WORK-SAVER PIPE TOOLS
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HAPPIER NEW YEAR
with Jenson Pumping Units

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"U. S." builds a dependable Electric Plant to fit every oil-field use . . . compact portables for emergency use . . . units in weather-proof housings . . . automatic units for camp lighting. AC and DC units—gasoline, diesel, and for operation on natural gas. Write for information.

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UNITED STATES MOTORS CORP.
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As nice a piece of platform orating as we have heard in a long time was Graham Moody's presentation at the annual meeting of the AAPG, Pacific Section, in the Los Angeles Ambassador Hotel. It was on the subject of reserves, and was illustrated with a series of charts and graphs that were easily legible from the back of the large auditorium, and were appropriately designed. The most interesting feature, however, was that the verbal exposition was impromptu; was just the right length for comfortable listening, and was delivered in a thoroughly human style that made it appreciable by laymen as well as experts, yet didn't detract one iota from its scientific value. The presentation opened with the parable of the little bull that went a long way, and closed with the one about a man who skidded on the ice at the top of a hilly road, and slid on his back to the bottom. En route, he scooped up a girl, to whom he said at the end of the ride, "You gotta get off here, lady, this is as far as I go."

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Incidentally, in a very nice gesture, the boys who have been attending Martin Van Couvering's AAPG study sessions in ever-increasing numbers, gave a demonstration of their gratitude for his fine work by banding together and giving him a gold wrist watch. Martin was pretty much surprised, and naturally very tickled, to be thus tangibly informed that his efforts were approved. We understand that following the little ceremony, he was seen out at the back of the Ambassador in the late afternoon, with his left sleeve rolled up, and the new chronometer laid bare, checking on the accuracy of the California sunset. Another high honor fell to Martin; the following day when he was elected president of the Pacific Section, AAPG succeeding Bob Atwill.

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Word comes via the oil field underground that Howard Said, a recent acquisition of Union's land department has been transferred to Santa Maria. For those who are not too well acquainted with this budding Sarazen, we might mention that in prewar times he was unquestionably the oil industry's most proficient barefoot golfer. A considerable portion of his divot lofting forays, on which we frequently accompanied him, took him high on the rugged crags of the Sunset Club at Burbank. With his shoes off, he found that he could grip the dizzy ledges more firmly. Most golfers prefer to either go around or chip over an obstacle, but Howard was a direct actionist—he always tried to go through them. For this reason, we found it distinctly advisable to walk behind him.

•

Occasionally, the drabness of the petrolic workaday scene is illuminated by the colorful light of romance. Take, for example, the case of Marjorie Kamm, long time secretary to Dr. Bob Clark, chief geologist for Western Gulf Petroleum Company. Marjorie was known to every geologist, geophysicist and paleontologist on the West Coast, because of her helpfulness, and the friendly way she performed, under cover, for all the geological conventions, AIME meetings, and whatnot, in which her boss was everlastingly involved. Out to the Coast came Dr. W. C. Krumbein, professor of geology at Northwestern University, to consult with Western Gulf on sedimentary problems, and at the same time to fall like a ton of bricks for Marjorie. The regard was apparently a reciprocal affair, for in no time at all, Dr. Krumbein had acquired a wife, and Dr. Clark had lost a secretary. We haven't heard yet whether or not anything was accomplished in the matter of the sedimentary problems, or whether they were completely submerged in the more conjugal matters that suddenly developed.

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Talking interestingly on Saudi Arabian operations of "Arabamco" the other night at the Los Angeles Nomads' meeting in the Clark Hotel, Phil McConnell said the one thing above all others that had contributed most to the success of the project, was the invention by Arabam engineers of a new type tire, especially designed for desert travel. This was suggested by the camel's foot, which splays out into larger size when he puts his heft on it, thus reducing the weight per square inch, and coincidentally reducing the depth of penetration in the sand. The tires were designed to give a considerable spread under the weight of the vehicle. They consequently carry very low air pressure—passenger cars, 8 or 9 pounds and trucks about 20. This development greatly facilitated transportation, a major problem in the area. On the same topic, Jan Law points out that the same idea had been worked on and perfected independently by the French, and that he personally had chauffeured vehicles so equipped across stretches in Europe.

Elmer Decker, one of the founders of Nomads, came to the meeting straight from a duck blind, where he spent a rainy afternoon with results that might explain the use of the word "blind" in this connection. Anyway, hunters are like fishermen, they don't need to bag anything more than their pants to have a good time, and Deck appeared to have enjoyed the excursion. It was somewhat spoiled, however, when he got back and found the plant partly under water as an aftermath of the storm. Nevertheless, his presence at the meeting in Los Angeles shows that he still wasn't too badly disturbed. It might be mentioned in passing that Henry Pullman did an extra fine job of introducing one of the biggest assemblies of foreign operators ever to appear at a Nomads meeting. No question, this boy knows the foreign fields, and with few exceptions everybody in them. By the same token, if the oil industry ever has ambitions to form a barbershop quartet, we can recommend the extemporaneous aggregation that blossomed into being at this same shindig. It consisted of Frank Carter, General Petroleum Corporation; Phil McConnell, Arabamco; Hal Coops, Patterson-Ballagh, and Ray Humphreys, Axelson Manufacturing Company.

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We note that there is considerable oil excitement in Canoga Park, out on the Ventura highway, which reminds us that W. W. Orcutt tried for the last 20 years of his life to find a property that *didn't* have oil on it. He wanted so badly to buy a comfortable place where he could settle without fear of being disturbed. But wherever he went, the geologists followed, and one after another he had to abandon his properties to make way for oil wells. At last, he found a nice ranch out in Canoga Park that seemed to be beyond the interest of the oil prospectors. On this he lived to the end of his days in peace and comfort. Now, there is at least a faint possibility that this one, too, might be sitting on top of an oil field.

•

Which recalls that back in the old days around Santa Paula, there used to be a somewhat sketchy road between the town, such as it was, and an oil camp at Adams Canyon, seven tortuous and rugged miles distant. Chester Brown, in charge of operations, made himself very unpopular with the camp teamster by frequently remarking that he could run to town faster than the latter's horses. There thus developed a feud that eventually brought forth a challenge — and a date was duly set for the contest. The horses were heavy, so it was generally conceded that the runner would forge well ahead in the early stages, and since the road wasn't too well defined, it was agreed that Chester Brown should carry with him a number of small light flags and implant them at intervals to indicate to the teamster the route taken.

On the appointed day, the contestants took their places, and with the rousing cheers of the assembled drilling crews ringing in their ears, the historic race began. With the discharge of the starting gun, Chester Brown took off like a rather stout hare, and in a classic burst of speed had disappeared around the first corner before the horses had recovered from their fright. That was the last the driver saw of him during the race. One by one, as he turned the succession of hairpin turns, he saw the flags, properly located, and as each one came in sight, he lashed his horses furiously in his desperation to catch the speed demon.

But, he never made it! When Chester Brown dashed around that first turn, it was the end of the race as far as he was concerned, for, as soon as he was out of sight, he dodged into the brush and, after the team had gone by, leisurely ambled back to the starting place. The flags had been set up by one of the night men hours before, and when the chargrined driver eventually reached town it was only to learn from the spectators there, also in on the deal, that Chester Brown had got tired waiting for him and had gone back to camp.

•

Returning to the news of the moment, it has just been announced as we write that among the westerners elected to the directorate of the API at Chicago recently is Ted Sutter, the Baker Oil Tools exec. Ted already has more jobs than the Gilbert and Sullivan character who became "ruler of the King's Navee." One of his big ambitions is to arouse the oil industry to a realization of the value of its own colorful history, as a public relations medium. As historian for the Petroleum Pioneers, he is hopeful of eventually ferreting out the significant facts of California's oil history, and directing the compilation of a story that he is sure will establish beyond doubt the virtue of the free enterprise system. By way of relaxation, Ted occasionally plays a game remotely resembling golf, but his real hobby is a daughter who not so long ago graduated *summa cum laude* in psychology from Stanford.

Has 99 stores

With the opening this month of The National Supply Company's store in Rock Springs, Wyoming, the company now has 99 stores in the oil fields of this country and Canada, according to A. W. McKinney, Toledo, Ohio, vice president and general manager of sales. C. W. Morris, who has been manager of the Casper, Wyoming, store, is manager of the company's newest outlet.

FROM NEAR THE ARTIC CIRCLE at Fort McNorman to below the Straits of Magellan or an island off the southern tip of South America you will find Sperry-Sun Instruments in use.

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Offices: Philadelphia, Pa.; Houston, Corpus Christi, Falfurrias, Marshall, Odessa, Texas; Lafayette, La.; Long Beach, Bakersfield, Calif.; Oklahoma City, Okla.; Casper, Wyo.

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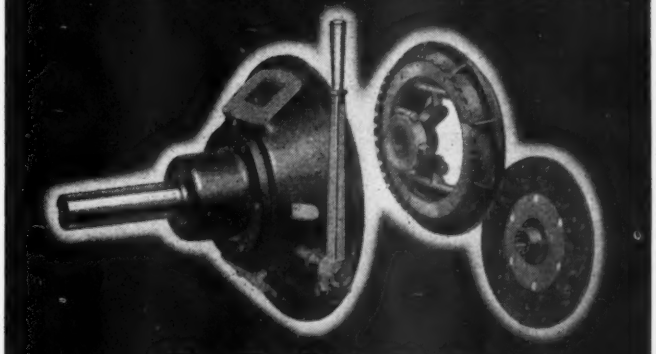

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FINE ADJUSTMENT
ACCURATE BALANCE
S.A.E. DIMENSIONS

* The housing supports the drive shaft, which is mounted on a main bearing in the housing and a pilot bearing in the engine flywheel. The clutch is mounted on the drive shaft, which is extended to serve as the output shaft for the external drive, and may carry a pulley, gear, sprocket, or drive—through a coupling.

Send for This Handy Bulletin

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FOR ACCURATE DRILLING TIME DATA

Geograph Mechanical Well Logging Service

The excerpts below are taken from a letter recently received from Mr. G. Frederick Shepherd, Consulting Geologist, of New Orleans, La.

"I have used the Geograph on over 95% of the wells which I have supervised during the past five years and I wish to commend you on the quality of service which has been rendered by your organization during this period, and on the improvements you have made in your equipment in the past year or two.

"Experiences during the past two years have convinced me that a drilling time recorder has become a 'must' for drillers, tool pushers, and operators as well.

"During these years the use of drilling time logs has saved in direct economies several times the cost of the rental of the machine on each job, and in some cases information thus gained in advance of electrical logging has been of immeasurable value."

(Signed) G. Frederick Shepherd

Reasonable rental rates . . . Write for details now.

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Shell organization changes

To keep pace with expansion in exploration, production, and related activities of Shell Oil Company, Inc., A. J. Galloway, vice president, has announced certain organization changes for the East-of-the-Rockies territory.

Overall production and exploration activities east of the Rockies will continue to be coordinated from the Houston office, he said; however, for administrative purposes, the territory will be divided into four areas, namely, the present Tulsa area and three new areas: Midland, Houston, and New Orleans, each with an area manager responsible for all operations in his area.

Simultaneously, an advisory staff is being appointed in Houston, representing every major phase of operations, to coordinate the activities of the four areas and render specialized services.

The Tulsa area will continue under R. B. Roark, vice president and manager, Galloway said; and the following new appointments have been made: W. A. Alexander, manager of the Houston area; B. Dykstra, manager of the Midland area, and E. G. Robinson, manager of the New Orleans area.

W. A. Alexander

E. G. Robinson

B. Dykstra

W. A. Alexander, with nearly 20 years' service, joined Shell in 1928 as district field engineer at White Castle, Louisiana, and has risen through the ranks in the production department, becoming assistant production manager in May, 1942. In 1944, he became manager of the production department in Houston and remained in that position until becoming manager of the newly created Houston area.

E. G. Robinson, with 21 years' experience, began his career with Shell in February, 1925, as district geologist at San Antonio. Subsequently, he filled positions in almost every division of Shell Oil Company, and in December, 1943, was appointed exploration manager of the Texas-Gulf area.

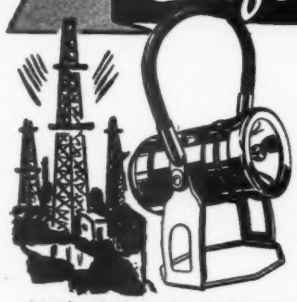
B. Dykstra has been with Shell since 1926 and has had extensive production experience throughout the Shell company. He has held various positions in the Gulf Coast until 1936, when he was transferred to Tulsa as chief exploitation engineer, remaining in that position until he was transferred to California in 1939. He left California in August of 1940, to accept a position with Shell of Colombia in South America, and his last assignment there was that of technical manager.

To larger headquarters

Consolidation of executive and engineering headquarters in new offices has been announced by T. Ellwood Webster, president of Catalytic Construction Company. The new address will be 1600 Walnut Street, Philadelphia 3, Pennsylvania.

Executive offices previously had been at 1608 Walnut Street and engineering offices in the Lewis Tower, Philadelphia. Expansion of company activities has made necessary increased working area, Webster pointed out.

Safe - Thrifty



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Book Reviews

• **What Industry Owes to Chemical Sciences, A Symposium,** *by Richard B. Pilcher and Frank Butler-Jones—with Fifty Contributors. Published by Chemical Publishing Company, Inc., 234 King Street, Brooklyn 31, New York. Price, $5.00. Pages, 372.*

Bearing in mind that this book is intended for the general reader as well as for chemical students, the authors, in supplying definite evidence in concrete form of the utility of chemistry in the development of industry, have endeavored to avoid technical details that cannot easily be understood by those who have little knowledge of science.

The individual articles were referred to selected authors in order that the various industries in which chemistry had been applied with marked advantage might receive authoritative treatment.

Issued by authority of the Council of the Royal Institute of Chemistry, this book shows that there is no reason to depreciate the value of the work of British men of science, who, often in the face of small encouragement, have played their part in industrial development.

• **Petroleum Production, Volume II, the Optimum Rate of Production,** *by Park J. Jones. Published by Reinhold Publishing Corporation, 330 West 42nd Street, New York 18, New York. Price, $4.50. Pages, 293.*

This volume, the second in a series on oil production, by Park J. Jones, deals exhaustively with optima for various fields. Volume I covered the mechanics of production of oil, condensate, and natural gas.

In his preface the author states that the optima for a fixed producing and operating method include the optimum investment, the optimum rate for production and the optimum present value. The prospective difference between the optima for two, or more, possible producing and operating methods is the basis for estimating the optimum method for a reservoir.

The optima for individual leases and for a reservoir as a whole may then be compared. Such comparisons keep open the possibility of adjusting differences, of reconciling conflicting interest, and of arriving at just and equitable estimates.

More significant than estimating the optimum rate of production for a given producing and operating method is the selection of an optimum producing and operating method. This volume's information on the optimum rate of production is a tool for optimizing producing and operating methods.

• **Petroleum Almanac.** *Published by the National Industrial Conference Board, 247 Park Avenue, New York 17, New York. Price, Paper: $4.00, Cloth, $5.00. Pages, 420.*

This book is a statistical record of the petroleum industry in the United States and foreign countries. The Petroleum Almanac has more than four hundred statistical tables showing the economic significance of the industry, its place in the nation's distributive structure, tax revenues, and the growing importance of natural gas.

The Almanac is divided into ten major sections which include statistical tables and text on production, transportation, refining, marketing, distribution, utilization, finances, labor, regulatory bodies, taxation, alternate sources of enery prices, value, and world petroleum supplies. The increasing importance of natural gas has earned that product a thorough inspection and analysis. Figures on natural gas wells go back to 1899.

• **The Institute of Petroleum Electrical Code.** *Published by the Institute of Petroleum, Manson House, 26, Portland Place, London, W.1. Price 5s. Od., postage free. Pages, 77.*

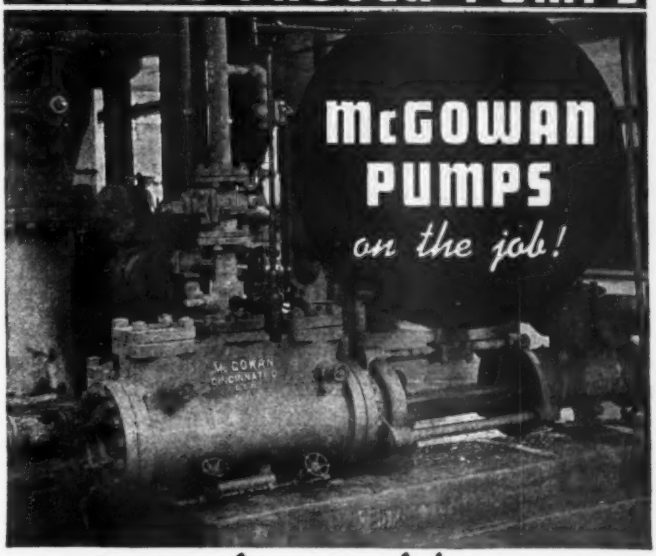
This suggested Code of Electrical Practice applicable to conditions in the petroleum industry has been issued by the Institute of Petroleum. It fills a demand for a document that is representative of the considered views of the oil industry, based on experience of its special conditions, and that gives general guidance on the selection and methods of installation of suitable electrical equipment for each type of operation encountered.

Not confined to the use of electricity for lighting, power, and instruments, it takes account also of the problems arising from accumulations of static electricity and of protective measures that may be taken against the effects of electricity in the form of lightning.

Though the rules and recommendations embodying the practice suggested in the code are comparatively brief, the arguments upon which they are based are explained and described in a number of schedules.

The Council of the Institute points out that the Code represents their present views, and is issued provisionally at this stage with a view to experience being gained in its application, after which it will be reviewed and either confirmed or amended as may be desirable.

SERVICE PROVEN PUMPS



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. . write our Engineering Dept., McGowan Pump Division, Leyman Mfg. Corp., Cincinnati 2, Ohio, for complete information.

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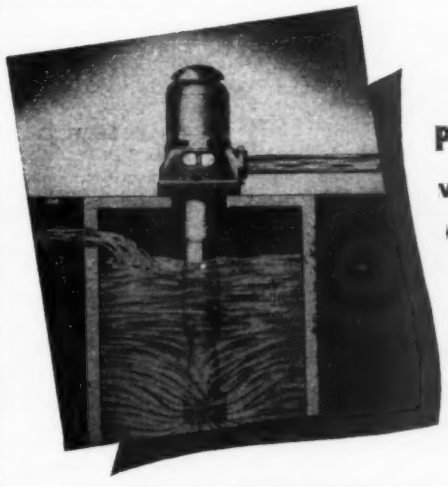

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